Evolution and Extinction of Mammals

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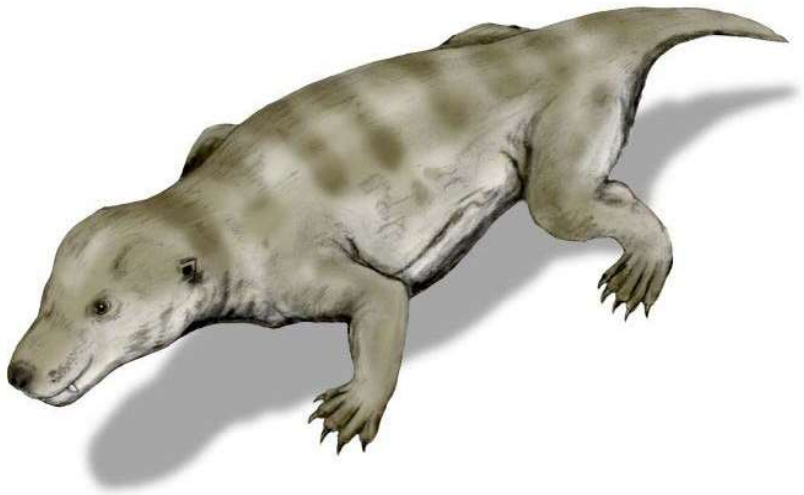
Evolution of Mammals



Restoration of *Thrinaxodon*, a member of the cynodont group, which includes the ancestors of mammals.

The **evolution of mammals** within the synapsid lineage (mammal-like-reptiles) was a gradual process that took approximately 70 million years, beginning in the mid-Permian. By the mid-Triassic, there were many species that looked like mammals, and the first true mammals appeared in the early Jurassic. The earliest known marsupial, *Sinodelphys*, appeared 125 million years ago in the early Cretaceous, around the same time as *Eomaia*, the first known eutherian (member of placentals' "parent" group); and the earliest known monotreme, *Teinolophos*, appeared two million years later. After the Cretaceous-Tertiary extinction wiped out the non-avian dinosaurs (birds are generally regarded as the surviving dinosaurs) and several other mammalian groups, placental and marsupial mammals diversified into many new forms and ecological niches throughout the Tertiary, by the end of which all modern orders had appeared.

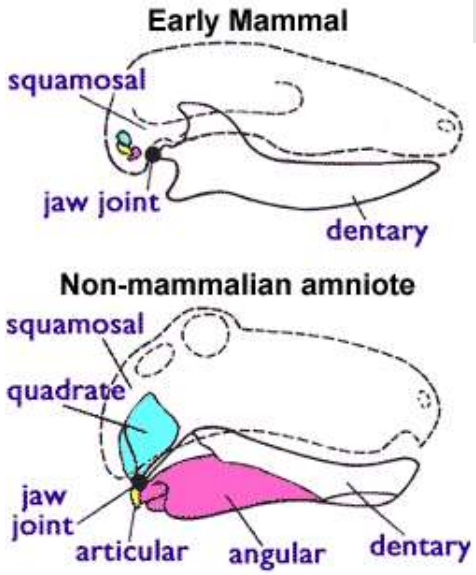
From the point of view of phylogenetic nomenclature, mammals are the only surviving synapsids. The synapsid lineage became distinct from the sauropsid ("reptile") lineage in

the late Carboniferous period, between 320 and 315 million years ago, and were the most common and largest land vertebrates of the Permian period. But in the Triassic period a previously obscure group of sauropsids, the archosaurs, became the dominant vertebrates and one archosaur group, the dinosaurs, dominated the rest of the Mesozoic era. These changes forced the Mesozoic mammaliforms ("nearly mammals") into nocturnal niches, and may have contributed greatly to the development of mammalian traits such as endothermy, hair and a large brain. Later in the Mesozoic mammals spread into other ecological niches, for example aquatic, gliding and even preying on dinosaurs.

Most of the evidence consists of fossils. For many years fossils of Mesozoic mammals and their immediate ancestors were very rare and fragmentary, but since the mid 1990s there have been many important new finds, especially in China. The relatively new techniques of molecular phylogenetics have also shed light on some aspects of mammalian evolution by estimating the timing of important divergence points for modern species. When used carefully, these techniques often, but not always, agree with the fossil record.

Although mammary glands are a signature feature of modern mammals, little is known about the evolution of lactation, and virtually nothing is known about the evolution of another distinctive feature, the neocortex region of the brain. This is because these soft tissues are not often preserved in the fossil record. Hence, most study of the evolution of mammals centers around the development of the middle ear bones from components of the ancestral amniote jaw joint. Other much-studied aspects include the evolution of erect limb posture, a bony secondary palate, fur and hair, and warm-bloodedness.

Definition of "mammal"



Mammalian and non-mammalian jaws. In the mammal configuration, the quadrate and articular bones are much smaller and form part of the middle ear. Note that in mammals the lower jaw consists of only the dentary bone.

Living mammal species can be identified by the presence of milk-producing mammary glands in females. Other features are required when classifying fossils, since mammary glands and other soft-tissue features are not visible in fossils.

Paleontologists therefore use a distinguishing feature that is shared by all living mammals (including monotremes) but is not present in any of the early Triassic therapsids: Mammals use two bones for hearing that all other amniotes use for eating. The earliest amniotes had a jaw joint composed of the articular (a small bone at the back of the lower jaw) and the quadrate (a small bone at the back of the upper jaw). All non-mammalian amniotes use this system including lizards, crocodilians, dinosaurs (and their descendants the birds), and therapsids. But mammals have a different jaw joint, composed only of the dentary (the lower jaw bone, which carries the teeth) and the squamosal (another small skull bone). In mammals, the quadrate and articular bones have become the incus and malleus bones in the middle ear.

Mammals also have a double occipital condyle; they have two knobs at the base of the skull that fit into the topmost neck vertebra, and other vertebrates have a single occipital condyle. But paleontologists use only the jaw joint and middle ear as criteria for identifying fossil mammals, as it would be confusing if they found a fossil that had one feature but not the other (e.g. a mammalian jaw and ear but a non-mammalian single occipital condyle).

Due to the incremental changes in transitional fossils, it has been said

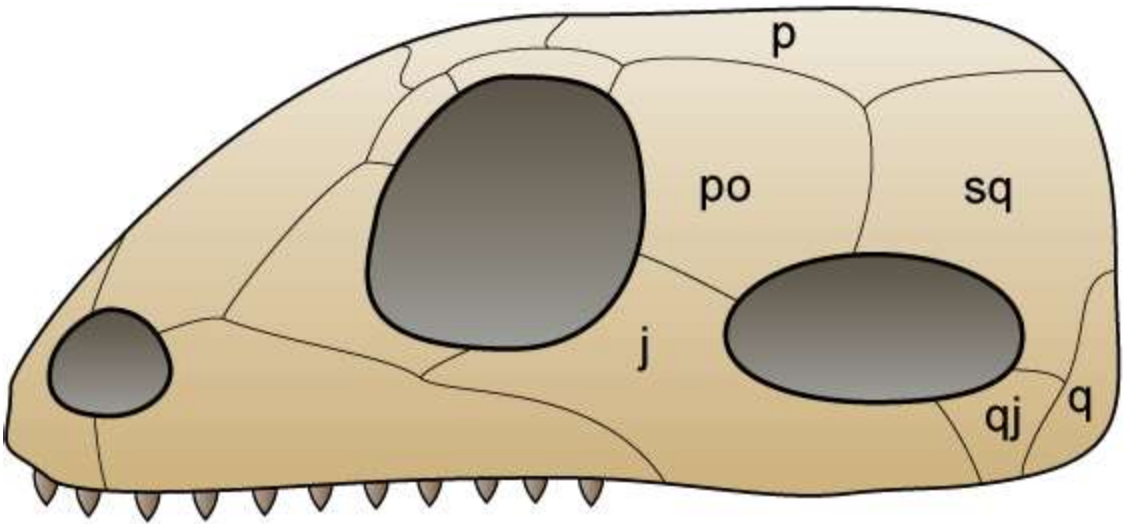
We may again ask the question, What is a mammal? Where we draw the line between reptile and mammal has no biological significance. It is purely a matter of convenience. There are two obvious choices, both immediately following a period of rapid evolution that make as definite a break as we can hope to find.

Amniotes

The first fully terrestrial vertebrates were amniotes — their eggs had internal membranes that allowed the developing embryo to breathe but kept water in. This allowed amniotes to lay eggs on dry land, while amphibians generally need to lay their eggs in water (a few amphibians, such as the Surinam toad, have evolved other ways of getting round this limitation). The first amniotes apparently arose in the late Carboniferous from the ancestral reptiliomorphs.

Within a few million years two important amniote lineages became distinct: mammals' synapsid ancestors and the sauropsids, from which lizards, snakes, crocodilians, dinosaurs and birds are descended. The earliest known fossils of synapsids and sauropsids (such as Archaeothyris and Hylonomus resp.) date from about 320 to 315 million years ago. Unfortunately it is difficult to be sure about when each of them evolved, since vertebrate fossils from the late Carboniferous are very rare, and therefore the actual first occurrences of each of these types of animal might have been considerably earlier.

Synapsids



The original synapsid skull structure has one hole behind each eye, in a fairly low position on the skull (lower right in this image).

Synapsid skulls are identified by the distinctive pattern of the holes behind each eye, which served the following purposes:

- made the skull lighter without sacrificing strength.
- saved energy by using less bone.
- probably provided attachment points for jaw muscles. Having attachment points further away from the jaw made it possible for the muscles to be longer and therefore to exert a strong pull over a wide range of jaw movement without being stretched or contracted beyond their optimum range.

Early Permian terrestrial fossils indicate that one synapsid group, the pelycosaurs, were the most common land vertebrates of their time and included the largest land animals of the time.

Therapsids

Therapsids descended from pelycosaurs in the middle Permian and took over their position as the dominant land vertebrates. They differ from pelycosaurs in several features of the skull and jaws, including larger temporal fenestrae and incisors that are equal in size.

The therapsids went through a series of stages, beginning with animals that were very like their pelycosaur ancestors and ending with some that could easily be mistaken for mammals:

- gradual development of a bony secondary palate. Most books and articles interpret this as a prequisite for the evolution of mammals' high metabolic rate,

because it enabled these animals to eat and breathe at the same time. But some scientists point out that some modern ectotherms use a fleshy secondary palate to separate the mouth from the airway, and that a *bony* palate provides a surface on which the tongue can manipulate food, facilitating chewing rather than breathing. The interpretation of the bony secondary palate as an aid to chewing also suggests the development of a faster metabolism, since chewing makes it possible to digest food more quickly. In mammals the palate is formed by two specific bones, but various Permian therapsids had other combinations of bones in the right places to function as a palate.

- the dentary gradually becomes the main bone of the lower jaw.
- progress towards an erect limb posture, which would increase the animals' stamina by avoiding Carrier's constraint. But this process was erratic and very slow — for example: all herbivorous therapsids retained sprawling limbs (some late forms may have had semi-erect hind limbs); Permian carnivorous therapsids had sprawling forelimbs, and some late Permian ones also had semi-sprawling hindlimbs. In fact, modern monotremes still have semi-sprawling limbs.
- in the Triassic, progress towards the mammalian jaw and middle ear.
- there is plausible evidence of hair in Triassic therapsids, but none for Permian therapsids.
- some scientists have argued that some Triassic therapsids show signs of lactation.

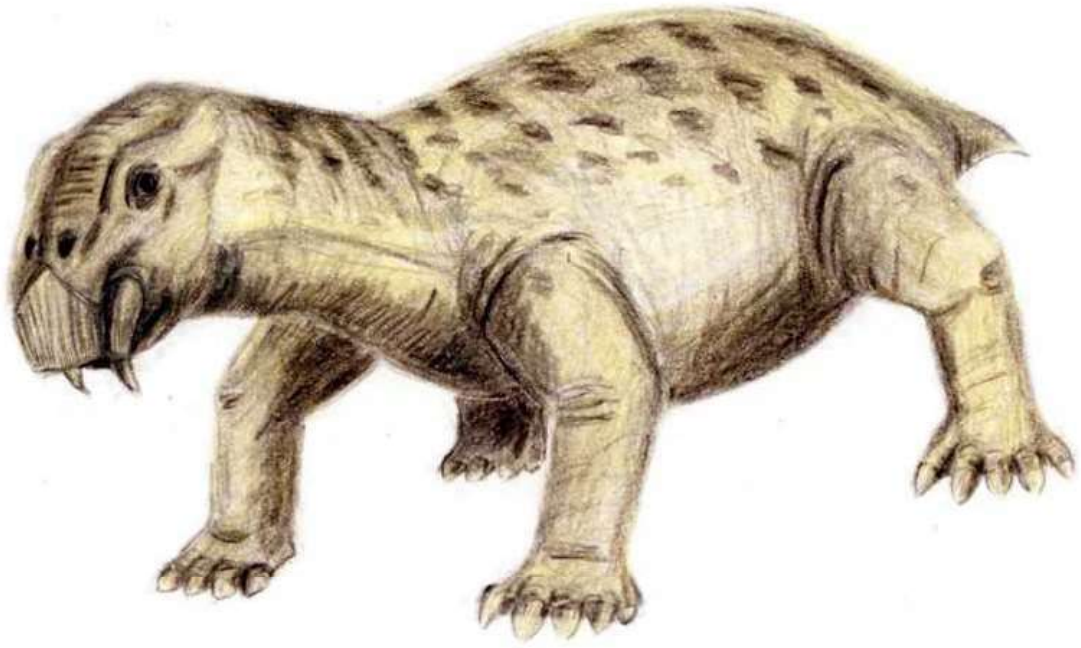
Biarmosuchia

The Biarmosuchia were the most primitive and pelycosaur-like of the therapsids.

Dinocephalians

Dinocephalians ("terrible heads") were large, some as large as a rhinoceros, and included both carnivores and herbivores. Some of the carnivores had semi-erect hindlimbs, but all dinocephalians had sprawling forelimbs. In many ways they were very primitive therapsids, for example they had no secondary palate and their jaws were rather "reptilian".

Anomodonts



Lystrosaurus, one of the few species of dicynodonts that survived the Permian-Triassic extinction event

The anomodonts ("anomalous teeth") were the most successful of the herbivorous therapsids — one sub-group, the dicynodonts, survived almost to the end of the Triassic. But anomodonts were very different from modern herbivorous mammals, as their only teeth were a pair of fangs in the upper jaw and it is generally agreed that they had beaks like those of birds or ceratopsians.

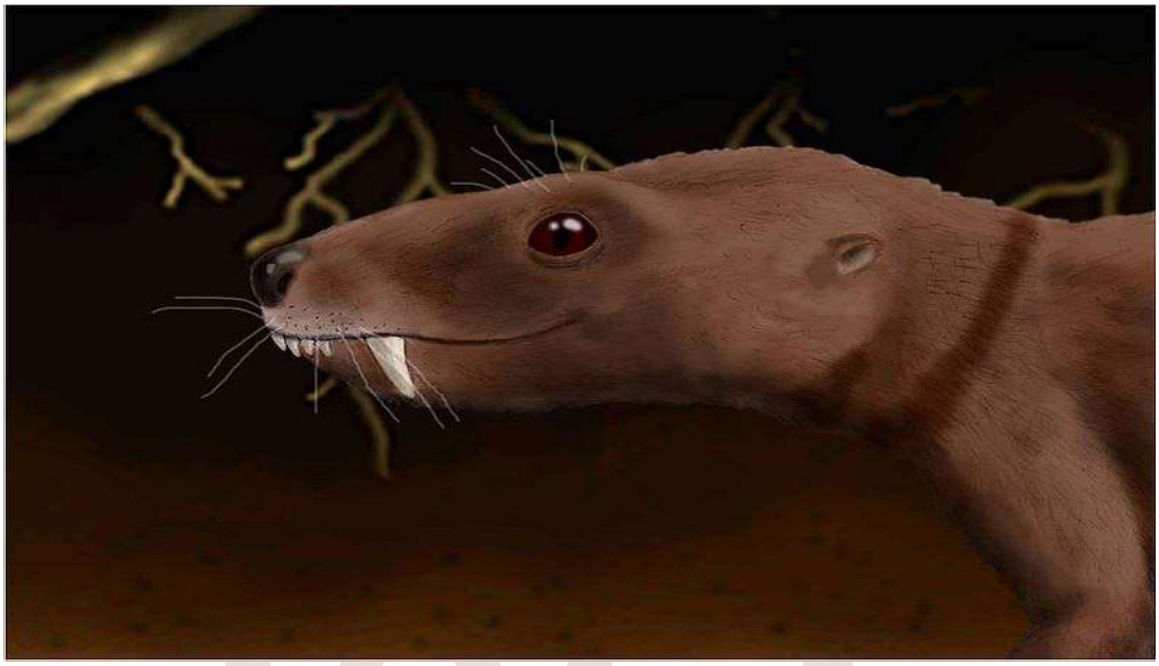
Theriodonts

The theriodonts ("beast teeth") and their descendants had jaw joints in which the lower jaw's articular bone tightly gripped the skull's very small quadrate bone. This allowed a much wider gape, and one group, the carnivorous gorgonopsians ("gorgon faces"), took advantage of this to develop "sabre teeth". But the theriodont's jaw hinge had a longer term significance — the much reduced size of the quadrate bone was an important step in the development of the mammalian jaw joint and middle ear.

The gorgonopsians still had some primitive features: no bony secondary palate (but other bones in the right places to perform the same functions); sprawling forelimbs; hindlimbs that could operate in both sprawling and erect postures. But the therocephalians ("beast heads"), which appear to have arisen at about the same time as the gorgonopsians, had additional mammal-like features, e.g. their finger and toe bones had the same number of

phalanges (segments) as in early mammals (and the same number that primates have, including humans).

Cynodonts



Artist's conception of the cynodont *Trirachodon* within a burrow

The cynodonts, a theriodont group that also arose in the late Permian, include the ancestors of all mammals — one sub-group, the trithelodonts, is widely regarded as the most likely to contain mammals' ancestor. Cynodonts' mammal-like features include further reduction in the number of bones in the lower jaw; a secondary bony palate; cheek teeth with a complex pattern in the crowns; the brain filled the endocranial cavity.

Multi-chambered burrows have been found, containing as many as 20 skeletons of the Early Triassic cynodont *Trirachodon*; the animals are thought to have been drowned by a flash flood. The extensive shared burrows indicate that these animals were capable of complex social behaviors.

Triassic takeover

The catastrophic Permian-Triassic mass extinction killed off about 70 percent of terrestrial vertebrate species, and the majority of land plants. As a result

- Ecosystems and food chains collapsed, and the recovery took about 6 million years.
- The survivors had to re-start the struggle for dominance of their former ecological niches — even the cynodonts, which had seemed on the way to dominance at the end of the Permian.

But the cynodonts lost out to a previously obscure group of sauropsids, the archosaurs (which include the ancestors of crocodilians, dinosaurs and birds). This reversal of fortunes is often called the "Triassic takeover". Several explanations have been offered for it, but the most likely is that the early Triassic was predominantly arid and therefore archosaurs' superior water conservation gave them a decisive advantage (all known sauropsids have glandless skins and excrete uric acid, which requires less water to keep it sufficiently liquid than urea, which marsupial and placental mammals excrete and presumably therapsids excreted). The Triassic takeover was gradual — in the earliest part of the Triassic cynodonts were the main predators and lystrosaurs were the main herbivores, but by the mid-Triassic archosaurs dominated all the large carnivore and herbivore niches.

But the Triassic takeover may have been a vital factor in the evolution of cynodonts into mammals. The cynodonts' descendants were only able to survive as small, mainly nocturnal insectivores. As a result:

- The therapsid trend towards differentiated teeth with precise occlusion accelerated, because of the need to hold captured arthropods and crush their exoskeletons.
- Nocturnal life required advances in thermal insulation and temperature regulation to enable the ancestors of mammals to be active in the cool of the night.
- Acute senses of hearing and smell became vital.
    - This accelerated the development of the mammalian middle ear, and therefore of the mammalian jaw since bones that had been part of the jaw joint became part of the middle ear.
    - The increase in the size of the olfactory and auditory lobes of the brain increased brain weight as a total percentage of body weight. Brain tissue requires a disproportionate amount of energy. The need for more food to support the enlarged brains increased the pressures for improvements in insulation, temperature regulation and feeding.
- As a side-effect of the nocturnal life, discerning colors became less important (they lost two out of four opsins), and this is reflected in the fact that most mammals have poor color vision, including the "lower primates" such as lemurs.

From cynodonts to true mammals

Many uncertainties

While the Triassic takeover probably accelerated the evolution of mammals, it made life more difficult for paleontologists because good fossils of the nearly-mammals are extremely rare, mainly because they were mostly smaller than rats:

- They were largely restricted to environments that are less likely to provide good fossils. The best terrestrial environments for fossilization are floodplains, where seasonal floods quickly cover dead animals in a protective layer of silt that is later compressed into sedimentary rock. But floodplains are dominated by medium to

large animals, and the Triassic therapsids and near-mammals could not compete with archosaurs in the medium to large size range.
- Their delicate bones were vulnerable to being destroyed before they could be fossilized — by scavengers (including fungi and bacteria) and by being trodden on.
- Small fossils are harder to spot and more vulnerable to being destroyed by weathering and other natural stresses before they are discovered.

In fact it was said as recently as the 1980s that all the Mesozoic fossils of mammals and near-mammals could be contained in a few shoeboxes — and they were mostly teeth, which are the most durable of all tissues. Since then, the number of Mesozoic fossil mammals has increased, from 116 genera known in 1979 to about 310 in 2007, with an increase in quality such that "at least 18 Mesozoic mammals are represented by nearly complete skeletons".

As a result:

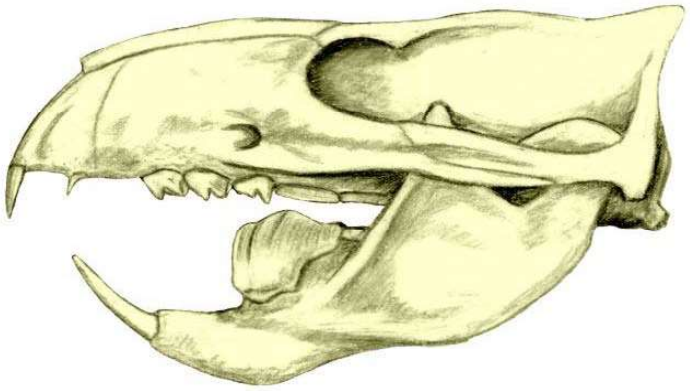
- In many cases it is difficult to assign a Mesozoic mammal or near-mammal fossil to a genus.
- All the available fossils of a genus seldom add up to a complete skeleton, and hence it is difficult to decide which genera are most like each other and therefore most likely to be closely-related. In other words, it becomes very difficult to classify them by means of cladistics, which is the most reliable and least subjective method currently available.

So the evolution of mammals in the Mesozoic is full of uncertainties, although there is no room for doubt that true mammals did first appear in the Mesozoic.

Mammals or mammaliformes?

One result of these uncertainties has been a change in the paleontologists' definition of "mammal". For a long time a fossil was considered a mammal if it met the jaw-ear criterion (the jaw joint consists only of the squamosal and dentary; and the articular and the quadrate bones have become the middle ear's malleus and incus). But more recently some paleontologists have usually defined "mammal" as the crown group mammals, i.e. the last common ancestor of monotremes, marsupials and placentals and all of its descendants. The need to address the animals that are more mammal-like than cynodonts, but less closely related to monotremes, marsupials and placentals, lead to erecting the group mammaliformes to accommodate these primitive forms. Mammaliformes is a paraphyletic taxon, representing the early radiation of mammals after the jaw-ear criterion. Although this now appears to be the majority approach, some paleontologists have resisted it because it simply moves most of the problems into the new taxon (a paraphyletic one at that) without solving the original problem; the Mammaliformes includes some animals with "mammalian" jaw joints and some with "reptilian" (articular-to-quadrate) jaw joints; and the newer definition of "mammal" and "mammaliformes" depend on last common ancestors of both groups, which have not yet been found.

Multituberculates

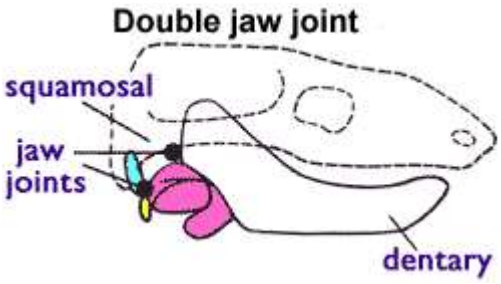


Skull of the multituberculate *Ptilodus*

Multituberculates (named for the multiple tubercles on their "molars") are often called the "rodents of the Mesozoic" but this is an example of convergent evolution rather than meaning that they are closely related to the Rodentia. At first sight they look like mammals: their jaw joints consists of only the dentary and squamosal bones, and the quadrate and articular bones are part of the middle ear; their teeth are differentiated, occlude and have mammal-like cusps; they have a zygomatic arch; the structure of the pelvis suggests that they gave birth to tiny helpless young, like modern marsupials. And they lived for over 120 million years (from mid Jurassic, about 160M years ago, to early Oligocene, about 35M years ago), which in terms of clade longevity would make them the most successful mammaliformes ever. But a closer look shows that they are very different from modern mammals:

- Their "molars" have two parallel rows of tubercles, unlike the tribosphenic (three-peaked) molars of early mammals.
- The chewing action is completely different. Mammals chew with a side-to-side grinding action, which means that usually the molars occlude on only one side at a time. Multituberculates' jaws were incapable of side-to-side movement and chewed by dragging the lower teeth backwards against the upper ones as the jaw closed.
- The anterior (forward) part of the zygomatic arch mostly consists of the maxilla (upper jawbone) rather than the jugal, and the jugal is a small bone in a little slot in the maxillary process (extension).
- The squamosal does not form part of the braincase.
- The rostrum (snout) is unlike that of mammals, in fact it looks more like that of a pelycosaur such as *Dimetrodon*. The multituberculate rostrum is box-like, with

the large flat maxillae forming the sides, the nasal the top, and the tall premaxilla at the front.

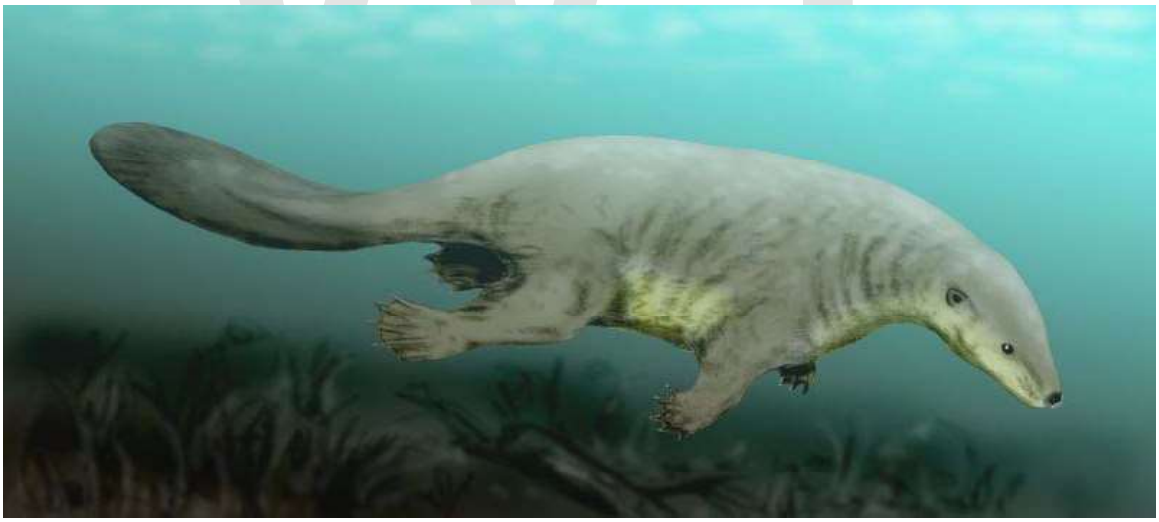


Morganucodontidae and other transitional forms had both types of jaw joint: dentary-squamosal (front) and articular-quadrate (rear).

Morganucodontidae

The Morganucodontidae first appeared in the late Triassic, about 205M years ago. They are an excellent example of transitional fossils, since they have both the dentary-squamosal and articular-quadrate jaw joints. They were also one of the first discovered and most thoroughly studied of the mammaliformes, since an unusually large number of morganucodont fossils have been found.

Docodonts



Reconstruction of *Castorocauda*. Note the fur and the adaptations for swimming (broad, flat tail; webbed feet) and for digging (robust limbs and claws).

The most notable member of the docodonts is *Castorocauda* ("beaver tail"), which lived in the mid Jurassic about 164M years ago and was first discovered in 2004 and described in 2006. *Castorocauda* was not a typical docodont (most were omnivores) and not a true mammal, but it is extremely important in the study of the evolution of mammals because

the first find was an almost complete skeleton (a real luxury in paleontology) and it breaks the "small nocturnal insectivore" stereotype:

- It was noticeably larger than most Mesozoic mammal-like fossils — about 17 in (43 cm) from its nose to the tip of its 5-inch (130 mm) tail, and may have weighed 500–800 g (18–28 oz).
- It provides the earliest absolutely certain evidence of hair and fur. Previously the earliest was *Eomaia*, a true mammal from about 125M years ago.
- It had aquatic adaptations including flattened tail bones and remnants of soft tissue between the toes of the back feet, suggesting that they were webbed. Previously the earliest known semi-aquatic mammal-like animals were from the Eocene, about 110M years later.
- *Castorocauda's* powerful forelimbs look adapted for digging. This feature and the spurs on its ankles make it resemble the platypus, which also swims and digs.
- Its teeth look adapted for eating fish: the first two molars had cusps in a straight row, which made them more suitable for gripping and slicing than for grinding; and these molars are curved backwards, to help in grasping slippery prey.

Hadrocodium

Hadrocodium skull. The jaw joint is fully mammalian (squamosal-dentary only) and farther forward than in earlier transitional forms.

The consensus family tree above shows *Hadrocodium* as an "aunt" of true mammals, while symmetrodonts and kuehneotheriids are more closely related to true mammals. But fossils of symmetrodonts and kuehneotheriids are so few and fragmentary that they are poorly understood and may be paraphyletic. On the other hand there are good fossils of *Hadrocodium* (about 195M years ago in the very early Jurassic) and they have some important features:

- The jaw joint consists only of the squamosal and dentary bones, and the jaw contains no smaller bones to the rear of the dentary, unlike the therapsid design.
- In therapsids and most mammaliformes the eardrum stretched over a trough at the rear of the lower jaw. But *Hadrocodium* had no such trough, which suggests its ear was part of the cranium, as it is in mammals — and hence that the former articular and quadrate had migrated to the middle ear and become the malleus and incus. On the other hand the dentary has a "bay" at the rear that mammals lack. This suggests that *Hadrocodium's* dentary bone retained the same shape that it would have had if the articular and quadrate had remained part of the jaw joint, and therefore that *Hadroconium* or a very close ancestor may have been the first to have a fully mammalian middle ear.
- Therapsids and earlier mammaliforms had their jaw joints very far back in the skull, partly because the ear was at the rear end of the jaw but also had to be close

to the brain. This arrangement limited the size of the braincase, because it forced the jaw muscles to run round and over it. *Hadrocodium's* braincase and jaws were no longer bound to each other by the need to support the ear, and its jaw joint was further forward. In its descendants or those of animals with a similar arrangement, the brain case was free to expand without being constrained by the jaw and the jaw was free to change without being constrained by the need to keep the ear near the brain — in other words it now became possible for mammal-like animals both to develop large brains and to adapt their jaws and teeth in ways that were purely specialized for eating.

The earliest true mammals

This part of the story introduces new complications, since true mammals are the only group that still has living members:

- One has to distinguish between extinct groups and those that have living representatives.
- One often feels compelled to try to explain the evolution of features that do not appear in fossils. This endeavor often involves Molecular phylogenetics, a technique that has become popular since the mid-1980s but is still often controversial because of its assumptions, especially about the reliability of the molecular clock.

Australosphenida and Ausktribosphenidae

Ausktribosphenidae is a group name that has been given to some rather puzzling finds that:

- appear to have tribosphenic molars, a type of tooth that is otherwise known only in placentals and marsupials.
- come from mid Cretaceous deposits in Australia — but Australia was connected only to Antarctica, and placentals originated in the northern hemisphere and were confined to it until continental drift formed land connections from North America to South America, from Asia to Africa and from Asia to India (the late Cretaceous map at shows how the southern continents are separated).
- are represented only by skull and jaw fragments, which is not very helpful.

Australosphenida is a group that has been defined in order to include the Ausktribosphenidae and monotremes. *Asfaltomylos* (mid- to late Jurassic, from Patagonia) has been interpreted as a basal australosphenid (animal that has features shared with both Ausktribosphenidae and monotremes; lacks features that are peculiar to Ausktribosphenidae or monotremes; also lacks features that are absent in Ausktribosphenidae and monotremes) and as showing that australosphenids were widespread throughout Gondwanaland (the old Southern hemisphere super-continent).

But recent analysis of *Teinolophos* suggests *Teinolophos* (about 115M years ago) was a "crown group" (advanced and relatively specialised) monotreme, so the basal (most primitive) monotremes must have appeared considerably earlier; that some alleged Australosphenids were also "crown group" monotremes (e.g. *Steropodon*); and that other alleged Australosphenids (e.g. *Ausktribosphenos*, *Bishops*, *Ambondro*, *Asfaltomylos*) are therefore more closely related to and possibly members of the Therian mammals.

Monotremes

The earliest known monotreme is *Teinolophos*, which lived about 123M years ago in Australia. Recent (2007, published 2008) analysis suggest that it was not a basal (primitive, ancestral) monotreme but a full-fledged platypus, and therefore that the platypus and echidna lineages diverged considerably earlier and that basal monotremes were even earlier.

A more recent study (2009), however, has suggested that while Teinolophis was a type of platypus, it also was a basal monotreme and predated the radiation of modern monotremes. The semi-aquatic lifestyle of platypuses prevented them from being outcompeted by the marsupials that migrated to Australia millions of years ago, since joeys need to keep attached to their mothers and would drown if their mothers ventured into water. Genetic evidence has determined that echidnas diverged from the platypus lineage as recently as 19-48M when they made their transition from semi-aquatic to terrestrial lifestyle.

Monotremes have some features that may be inherited from the original amniotes:

- they use the same orifice to urinate, defecate and reproduce ("monotreme" means "one hole") — as lizards and birds also do.
- they lay eggs that are leathery and uncalcified, like those of lizards, turtles and crocodilians.

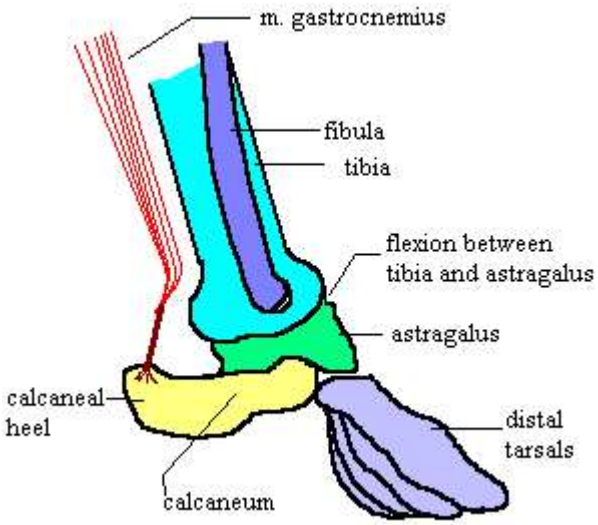
Unlike in other mammals, female monotremes do not have nipples and feed their young by "sweating" milk from patches on their bellies.

Of course these features are not visible in fossils, and the main characteristics from paleontologists' point of view are:

- a slender dentary bone in which the coronoid process is small or non-existent.
- the external opening of the ear lies at the posterior base of the jaw.
- the jugal bone is small or non-existent.
- a primitive pectoral girdle with strong ventral elements: coracoids, clavicles and interclavicle. Note: therian mammals have no interclavicle.
- sprawling or semi-sprawling forelimbs.

Theria

Theria ("beasts") is a name applied to the hypothetical group from which both metatheria (which include marsupials) and eutheria (which include placentals) descended. Although no convincing fossils of basal therians have been found (just a few teeth and jaw fragments), metatheria and eutheria share some features that one would expect to have been inherited from a common ancestral group:



Therian form of crurotarsal ankle. Adapted with permission from Palaeos

- no interclavicle.
- coracoid bones non-existent or fused with the shoulder blades to form coracoid processes.
- a type of crurotarsal ankle joint in which: the main joint is between the tibia and astragalus; the calcaneum has no contact with the tibia but forms a heel to which muscles can attach. (The other well-known type of crurotarsal ankle is seen in crocodilians and works differently — most of the bending at the ankle is between the calcaneum and astragalus).
- tribosphenic molars.

Tribosphenic molars have been found in fossils from Madagascar, which indicates that therian mammals are at least 167 million years old.

Metatheria

The living Metatheria are all marsupials ("animals with pouches"). A few fossil genera such as the Mongolian late Cretaceous *Asiatherium* may be marsupials or members of some other metatherian group(s).

The oldest known marsupial is *Sinodelphys*, found in 125M-year old early Cretaceous shale in China's northeastern Liaoning Province. The fossil is nearly complete and includes tufts of fur and imprints of soft tissues.

Didelphimorphia (common opossums of the Western Hemisphere) first appeared in the late Cretaceous and still have living representatives, probably because they are mostly semi-arboreal unspecialized omnivores.

The best-known feature of marsupials is their method of reproduction:

- The mother develops a kind of yolk sack in her womb that delivers nutrients to the embryo. Embryos of bandicoots, koalas and wombats additionally form placenta-like organs that connect them to the uterine wall, although the placenta-like organs are smaller than in placental mammals and it is not certain that they transfer nutrients from the mother to the embryo.
- Pregnancy is very short, typically 4 to 5 weeks. The embryo is born at a very young age of development, and is usually less than 2 in (5.1 cm) long at birth. It has been suggested that the short pregnancy is necessary to reduce the risk that the mother's immune system will attack the embryo.
- The newborn marsupial uses its forelimbs (with relatively strong hands) to climb to a nipple, which is usually in a pouch on the mother's belly. The mother feeds the baby by contracting muscles over her mammary glands, as the baby is too weak to suck. The newborn marsupial's need to use its forelimbs in climbing to the nipple has prevented the forelimbs from evolving into paddles or wings and has therefore prevented the appearance of aquatic or truly flying marsupials (although there are several marsupial gliders).

Palate of thylacine, showing one of the paired palatal fenestrae (top left), which are a signature feature of marsupials.

Although some marsupials look very like some placentals (the thylacine or "marsupial wolf" is a good example), marsupial skeletons have some features that distinguish them from placentals:

- Some, including the thylacine, have 4 molars. No placentals have more than 3.

- All have a pair of palatal fenestrae, window-like openings on the bottom of the skull (in addition to the smaller nostril openings).

Marsupials also have a pair of marsupial bones (sometimes called "epipubic bones"), which support the pouch in females. But these are not unique to marsupials, since they have been found in fossils of multituberculates, monotremes, and even eutherians — so they are probably a common ancestral feature that disappeared at some point after the ancestry of living placental mammals diverged from that of marsupials. Some researchers think the epipubic bones' original function was to assist locomotion by supporting some of the muscles that pull the thigh forwards.

Eutheria

The living Eutheria ("true beasts") are all placentals. But the earliest known eutherian, *Eomaia*, found in China and dated to 125M years ago, has some features that are more like those of marsupials (the surviving metatherians):

Fossil of *Eomaia* in the Hong Kong Science Museum.

- Epipubic bones extending forwards from the pelvis, which are not found in any modern placental, but are found in all other mammals — non-placental

eutherians, marsupials, monotremes and mammaliformes — and even in the cynodont therapsids that are closest to mammals. Their function is to stiffen the body during locomotion. This stiffening would be harmful in pregnant placentals, whose abdomens need to expand.
- A narrow pelvic outlet, which indicates that the young were very small at birth and therefore pregnancy was short, as in modern marsupials. This suggests that the placenta was a later development.
- 5 incisors in each side of the upper jaw. This number is typical of metatherians, and the maximum number in modern placentals is 3, except for homodonts such as the armadillo. But *Eomaia's* molar to premolar ratio (it has more pre-molars than molars) is typical of eutherians, including placentals, and not normal in marsupials.

Eomaia also has a Meckelian groove, a primitive feature of the lower jaw that is not found in modern placental mammals.

These intermediate features are consistent with molecular phylogenetics estimates that the placentals diversified about 110M years ago, 15M years after the date of the *Eomaia* fossil.

Eomaia also has many features that strongly suggest it was a climber, including several features of the feet and toes; well-developed attachment points for muscles that are used a lot in climbing; and a tail that is twice as long as the rest of the spine.

Placentals' best-known feature is their method of reproduction:

- The embryo attaches itself to the uterus via a large placenta via which the mother supplies food and oxygen and removes waste products.
- Pregnancy is relatively long and the young are fairly well-developed at birth. In some species (especially herbivores living on plains) the young can walk and even run within an hour of birth.

It has been suggested that the evolution of placental reproduction was made possible by retroviruses that:

- make the interface between the placenta and uterus into a syncytium, i.e. a thin layer of cells with a shared external membrane. This allows the passage of oxygen, nutrients and waste products but prevents the passage of blood and other cells, which would cause the mother's immune system to attack the fetus.
- reduce the aggressiveness of the mother's immune system (which is good for the foetus but makes the mother more vulnerable to infections).

From a paleontologist's point of view, eutherians are mainly distinguished by various features of their teeth, ankles and feet.

Expansion of ecological niches in the Mesozoic

There is still some truth in the "small, nocturnal insectivores" stereotype but recent finds, mainly in China, show that some mammaliforms and true mammals were larger and had a variety of lifestyles. For example:

- *Castorocauda*, a member of Docodonta which lived in the middle Jurassic about 164 million years, was about 42.5 cm (16.7 in) long, weighed 500–800 g (18–28 oz), had limbs that were adapted for swimming and digging and teeth adapted for eating fish.
- *Multituberculates*, are allotherians that survived for over 125 million years (from mid Jurassic, about 160M years ago, to early Oligocene, about 35M years ago) are often called the "rodents of the Mesozoic", because they had continuously-growing incisors like those of modern rodents.

Repenomamus sometimes preyed on young dinosaurs

- *Fruitafossor*, from the late Jurassic period about 150 million years ago, was about the size of a chipmunk and its teeth, forelimbs and back suggest that it broke open the nest of social insects to prey on them (probably termites, as ants had not yet appeared).
- *Volaticotherium*, allotherians from the boundary the early Cretaceous about 125M years ago, is the earliest-known gliding mammal and had a gliding membrane that

stretched out between its limbs, rather like that of a modern flying squirrel. This also suggests it was active mainly during the day.
- *Repenomamus*, tricodonts from the early Cretaceous 130 million years ago, was a stocky, badger-like predator that sometimes preyed on young dinosaurs. Two species have been recognized, one more than 1 m (39 in) long and weighing about 12–14 kg (26–31 lb), the other less than 0.5 m (20 in) long and weighing 4–6 kg (8.8–13 lb).

Evolution of major groups of living mammals

There are currently vigorous debates between traditional paleontologists ("fossil-hunters") and molecular phylogeneticists about how and when the true mammals diversified, especially the placentals. Generally the traditional paelontologists date the appearance of a particular group by the earliest known fossil whose features make it likely to be a member of that group, while the molecular phylogeneticists suggest that each lineage diverged earlier (usually in the Cretaceous) and that the earliest members of each group were anatomically very similar to early members of other groups and differed only in their genes. These debates extend to the definition of and relationships between the major groups of placentals — the controversy about Afrotheria is a good example.

Fossil-based family tree of placental mammals

Here is a very simplified version of a typical family tree based on fossils, based on Cladogram of Mammalia - Palaeos. It tries to show the nearest thing there is at present to a consensus view, but some paleontologists have very different views, for example:

- The most common view is that placentals originated in the southern hemisphere, but some paleontologists argue that they first appeared in Laurasia (old supercontinent containing modern Asia, N. America and Europe).
- Paleontologists differ about when the first placentals appeared, with estimates ranging from 20M years before the end of the Cretaceous to just after the end of the Cretaceous. And molecular biologists argue for a much earlier origin.
- Most paleontologists suggest that placentals should be divided into Xenarthra and the rest, but a few think these animals diverged later.

For the sake of brevity and simplicity the diagram omits some extinct groups in order to focus on the ancestry of well-known modern groups of placentals — **X** marks extinct groups. The diagram also shows the following:

- the age of the oldest known fossils in many groups, since one of the major debates between traditional paleontologists and molecular phylogeneticists is about when various groups first became distinct.
- well-known modern members of most groups.

This family tree contains some surprises and puzzles. For example:

- The closest living relatives of cetaceans (whales, dolphins, porpoises) are artiodactyls, hoofed animals, which are almost all pure vegetarians.
- Bats are fairly close relatives of primates.
- The closest living relatives of elephants are the aquatic sirenians, while their next relatives are hyraxes, which look more like well-fed guinea pigs.
- There is little correspondence between the structure of the family (what was descended from what) and the dates of the earliest fossils of each group. For example the earliest fossils of perissodactyls (the living members of which are horses, rhinos and tapirs) date from the late Paleocene but the earliest fossils of their "sister group" the Tubulidentata date from the early Miocene, nearly 50M years later. Paleontologists are fairly confident about the family relationships, which are based on cladistic analyses, and believe that fossils of the ancestors of modern aardvarks have simply not been found yet.

Family tree of placental mammals according to molecular phylogenetics

Molecular phylogenetics uses features of organisms' genes to work out family trees in much the same way as paleontologists do with features of fossils — if two organisms' genes are more similar to each other than to those of a third organism, the two organisms are more closely related to each other than to the third.

Molecular phylogeneticists have proposed a family tree that is very different from the one with which paleontologists are familiar. Like paleontologists, molecular phylogeneticists have different ideas about various details, but here is a typical family tree according to molecular phylogenetics: Note that the diagram shown here omits extinct groups, as one cannot extract DNA from fossils.

Here are the most significant of the many differences between this family tree and the one familiar to paleontologists:

- The top-level division is between Atlantogenata and Boreoeutheria, instead of between Xenarthra and the rest. But some molecular phylogeneticists have proposed a 3-way top-level split between Xenarthra, Afrotheria and Boreoeutheria.
- Afrotheria contains several groups that are only distantly related according to the paleontologists' version: Afroinsectiphilia ("African insectivores"), Tubulidentata (aardvarks, which paleontologists regard as much closer to odd-toed ungulates than to other members of Afrotheria), Macroscelidea (elephant shrews, usually regarded as close to rabbits and rodents). The only members of Afrotheria that paleontologists would regard as closely related are Hyracoidea (hyraxes), Proboscidea (elephants) and Sirenia (manatees, dugongs).
- Insectivores are split into 3 groups: one is part of Afrotheria and the other two are distinct sub-groups within Boreoeutheria.
- Bats are closer to Carnivora and odd-toed ungulates than to primates and Dermoptera (colugos).

- Perissodactyla (odd-toed ungulates) are closer to Carnivora and bats than to Artiodactyla (even-toed ungulates).

The grouping together of the Afrotheria has some geological justification. All surviving members of the Afrotheria originate from South American or (mainly) African lineages — even the Indian elephant, which diverged from an African lineage about 7.6 million years ago. As Pangaea broke up Africa and South America separated from the other continents less than 150M years ago, and from each other between 100M and 80M years ago. The earliest known eutherian mammal is *Eomaia*, from about 125M years ago. So it would not be surprising if the earliest eutherian immigrants into Africa and South America were isolated there and radiated into all the available ecological niches.

Nevertheless these proposals have been controversial. Paleontologists naturally insist that fossil evidence must take priority over deductions from samples of the DNA of modern animals. More surprisingly, these new family trees have been criticised by other molecular phylogeneticists, sometimes quite harshly:

- Mitochondrial DNA's mutation rate in mammals varies from region to region — some parts hardly ever change and some change extremely quickly and even show large variations between individuals within the same species.
- Mammalian mitochondrial DNA mutates so fast that it causes a problem called "saturation", where random noise drowns out any information that may be present. If a particular piece of mitochondrial DNA mutates randomly every few million years, it will have changed several times in the 60 to 75M years since the major groups of placental mammals diverged.

Timing of placental evolution

Recent molecular phylogenetic studies suggest that most placental orders diverged about 100M to 85M years ago, but that modern families first appeared in the late Eocene and early Miocene.

Some paleontologists object that no placental fossils have been found from before the end of the Cretaceous — for example *Maelestes gobiensis*, from about 75M years ago, is a eutherian but not a true placental. Many Cretaceous fossil sites contain well-preserved lizards, salamanders, birds, and mammals, but not the modern forms of mammals. It is likely that they simply did not exist, and that the molecular clock runs fast during major evolutionary radiations. On the other hand there is fossil evidence from 85 million years ago of hoofed animals that may be ancestors of modern ungulates.

Fossils of the earliest members of most modern groups date from the Paleocene, a few date from later and very few from the Cretaceous, before the extinction of the dinosaurs. But some paleontologists, influenced by molecular phylogenetic studies, have used statistical methods to extrapolate *backwards* from fossils of members of modern groups and concluded that primates arose in the late Cretaceous. However statistical studies of

the fossil record confirm that mammals were restricted in size and diversity right to the end of the Cretaceous, and rapidly grew in size and diversity during the Early Paleocene.

Evolution of mammalian features

Jaws and middle ears

Hadrocodium, whose fossils date from the early Jurassic, provides the first clear evidence of fully mammalian jaw joints and middle ears, in which the jaw joint is formed by the dentary and squamosal bones while the articular and quadrate move to the middle ear, where they are known as the incus and malleus. Curiously it is usually classified as a member of the mammaliformes rather than a as a true mammal.

One analysis of the monotreme *Teinolophos* suggested that this animal had a pre-mammalian jaw joint formed by the angular and quadrate bones and that the typical mammalian middle ear evolved twice independently, in monotremes and in therian mammals, but this idea has been disputed. In fact 2 of the suggestion's authors co-authored a later paper that reinterpreted the same features as evidence that *Teinolophos* was a full-fledged platypus, which means it would have had a mammalian jaw joint and middle ear.

Milk production (lactation)

It has been suggested that lactation's original function was to keep eggs moist. Much of the argument is based on monotremes (egg-laying mammals):

- Monotremes do not have nipples but secrete milk from a hairy patch on their bellies.
- During incubation, monotremes' eggs are covered in a sticky substance whose origin is not known. Before the eggs are laid, their shells have only three layers. Afterwards a fourth layer appears, and its composition is different from that of the original three. The sticky substance and the fourth layer may be produced by the mammary glands.
- If so, that may explain why the patches from which monotremes secrete milk are hairy — it is easier to spread moisture and other substances over the egg from a broad, hairy area than from a small, bare nipple.

Hair and fur

The first clear evidence of hair or fur is in fossils of *Castorocauda*, from 164M years ago in the mid Jurassic.

From 1955 onwards some scientists have interpreted the foramina (passages) in the maxillae (upper jaws) and premaxillae (small bones in front of the maxillae) of cynodonts as channels that supplied blood vessels and nerves to vibrissae (whiskers), and suggested that this was evidence of hair or fur. But foramina do not necessarily show that an animal

had vibrissae — for example the modern lizard *Tupinambis* has foramina that are almost identical to those found in the non-mammalian cynodont Thrinaxodon.

Erect limbs

The evolution of erect limbs in mammals is incomplete — living and fossil monotremes have sprawling limbs. In fact some scientists think that the parasagittal (non-sprawling) limb posture is a synapomorphy (distinguishing characteristic) of the Boreosphenida, a group that contains the Theria and therefore includes the last common ancestor of modern marsupials and placentals — and therefore that all earlier mammals had sprawling limbs.

Sinodelphys (the earliest known marsupial) and *Eomaia* (the earliest known eutherian) lived about 125M years ago, so erect limbs must have evolved before then.

Warm-bloodedness

"Warm-bloodedness" is a complex and rather ambiguous term, because it includes some or all of the following:

- **Endothermy**, i.e. the ability to generate heat internally rather than via behaviors such as basking or muscular activity.
- **Homeothermy**, i.e. maintaining a fairly constant body temperature.
- **Tachymetabolism**, i.e. maintaining a high metabolic rate, particularly when at rest. This requires a fairly high and stable body temperature, since biochemical processes run about half as fast if an animal's temperature drops by 10°C; most enzymes have an optimum operating temperature and their efficiency drops rapidly outside the preferred range.

Since scientists cannot know much about the internal mechanisms of extinct creatures, most discussion focuses on homeothermy and tachymetabolism.

Modern monotremes have a lower body temperature and more variable metabolic rate than marsupials and placentals. So the main question is when a monotreme-like metabolism evolved in mammals. The evidence found so far suggests Triassic cynodonts may have had fairly high metabolic rates, but is not conclusive.

Respiratory turbinates

Modern mammals have respiratory turbinates, convoluted structures of thin bone in the nasal cavity. These are lined with mucous membranes that warm and moisten inhaled air and extract heat and moisture from exhaled air. An animal with respiratory turbinates can maintain a high rate of breathing without the danger of drying its lungs out, and therefore may have a fast metabolism. Unfortunately these bones are very delicate and therefore have not yet been found in fossils. But rudimentary ridges like those that support respiratory turbinates have been found in Triassic therapsids such as *Thrinaxodon* and *Diademodon*, which suggests that they may have had fairly high metabolic rates.

Bony secondary palate

Mammals have a secondary bony palate, which separates the respiratory passage from the mouth, allowing them to eat and breathe at the same time. Secondary bony palates have been found in the more advanced cynodonts and have been used as evidence of high metabolic rates. But some cold-blooded vertebrates have secondary bony palates (crocodilians and some lizards), while birds, which are warm-blooded, do not have them.

Diaphragm

A muscular diaphragm helps mammals to breathe, especially during strenuous activity. For a diaphragm to work, the ribs must not restrict the abdomen, so that expansion of the chest can be compensated for by reduction in the volume of the abdomen and *vice versa*. The advanced cynodonts have very mammal-like rib cages, with greatly reduced lumbar ribs. This suggests that these animals had diaphragms, were capable of strenuous activity for fairly long periods and therefore had high metabolic rates. On the other hand these mammal-like rib cages may have evolved to increase agility. But the movement of even advanced therapsids was "like a wheelbarrow", with the hindlimbs providing all the thrust while the forelimbs only steered the animal, in other words advanced therapsids were not as agile as either modern mammals or the early dinosaurs. So the idea that the main function of these mammal-like rib cages was to increase agility is doubtful.

Limb posture

The therapsids had sprawling forelimbs and semi-erect hindlimbs. This suggests that Carrier's constraint would have made it rather difficult for them to move and breathe at the same time, but not as difficult as it is for animals such as lizards, which have completely sprawling limbs. But cynodonts (advanced therapsids) had costal plates that stiffened the rib cage and therefore may have reduced sideways flexing of the trunk while moving, which would have made it a little easier for them to breathe while moving . These facts suggest that advanced therapsids were significantly less active than modern mammals of similar size and therefore may have had slower metabolisms.

Insulation (hair and fur)

Insulation is the "cheapest" way to maintain a fairly constant body temperature, without consuming energy to produce more body heat. Therefore, possession of hair or fur would be good evidence of homeothermy but would not be such strong evidence of a high metabolic rate.

The first clear evidence of hair or fur is in fossils of *Castorocauda*, from 164M years ago in the mid Jurassic; arguments that advanced therapsids had hair are unconvincing.

Chapter- 2

Human Evolution

Human evolution, or *anthropogeny*, is the origin and evolution of *Homo sapiens* as a distinct species from other hominids, great apes and placental mammals. The study of human evolution uses many scientific disciplines, including physical anthropology, primatology, archaeology, linguistics and genetics.

The term "human" in the context of human evolution refers to the genus *Homo*, but studies of human evolution usually include other hominids, such as the Australopithecines, from which the genus *Homo* had diverged by about 2.3 to 2.4 million years ago in Africa. Scientists have estimated that humans branched off from their common ancestor with chimpanzees about 5–7 million years ago. Several species and subspecies of *Homo* evolved and are now extinct. These include *Homo erectus*, which inhabited Asia, and *Homo sapiens neanderthalensis*, which inhabited Europe. Archaic *Homo sapiens* evolved between 400,000 and 250,000 years ago.

The dominant view among scientists concerning the origin of anatomically modern humans is the "Out of Africa" or recent African origin hypothesis, which argues that *Homo sapiens* arose in Africa and migrated out of the continent around 50,000 to 100,000 years ago, replacing populations of *Homo erectus* in Asia and *Homo neanderthalensis* in Europe. Scientists supporting the alternative multiregional hypothesis argue that *Homo sapiens* evolved as geographically separate but interbreeding populations stemming from a worldwide migration of *Homo erectus* out of Africa nearly 2.5 million years ago. This theory has been contradicted by recent evidence, although it has been suggested that non Homo sapiens Neanderthal genomes may have contributed about 4% of non-African heredity, and the recently discovered *Denisova* hominin may have contributed 6% of the genome of Melanesians.

History of ideas

The word *homo*, the name of the biological genus to which humans belong, is Latin for "human". It was chosen originally by Carolus Linnaeus in his classification system. The word "human" is from the Latin *humanus*, the adjectival form of *homo*. The Latin "homo" derives from the Indo-European root, *dhghem*, or "earth".

Carolus Linnaeus and other scientists of his time also considered the great apes to be the closest relatives of humans due to morphological and anatomical similarities. The possibility of linking humans with earlier apes by descent only became clear after 1859 with the publication of Charles Darwin's *On the Origin of Species*. This argued for the idea of the evolution of new species from earlier ones. Darwin's book did not address the question of human evolution, saying only that "Light will be thrown on the origin of man and his history".

Fossil Hominid Evolution Display at The Museum of Osteology, Oklahoma City, USA

The first debates about the nature of human evolution arose between Thomas Huxley and Richard Owen. Huxley argued for human evolution from apes by illustrating many of the similarities and differences between humans and apes, and did so particularly in his 1863 book *Evidence as to Man's Place in Nature*. However, many of Darwin's early supporters

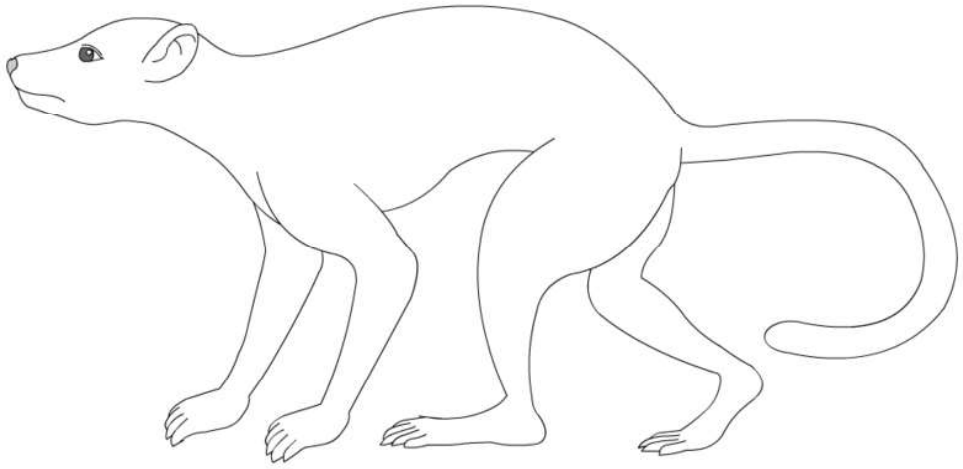
(such as Alfred Russel Wallace and Charles Lyell) did not agree that the origin of the mental capacities and the moral sensibilities of humans could be explained by natural selection. Darwin applied the theory of evolution and sexual selection to humans when he published *The Descent of Man* in 1871.

A major problem was the lack of fossil intermediaries. It was only in the 1920s that such fossils were discovered in Africa. In 1925, Raymond Dart described *Australopithecus africanus*. The type specimen was the Taung Child, an Australopithecine infant discovered in a cave. The child's remains were a remarkably well-preserved tiny skull and an endocranial cast of the individual's brain. Although the brain was small (410 cm^3), its shape was rounded, unlike that of chimpanzees and gorillas, and more like a modern human brain. Also, the specimen showed short canine teeth, and the position of the foramen magnum was evidence of bipedal locomotion. All of these traits convinced Dart that the Taung baby was a bipedal human ancestor, a transitional form between apes and humans.

The classification of humans and their relatives has changed considerably over time. The gracile Australopithecines are now thought to be ancestors of the genus *Homo*, the group to which modern humans belong. Both Australopithecines and *Homo sapiens* are part of the tribe Hominini. Recent data suggests Australopithecines were a diverse group and that *A. africanus* may not be a direct ancestor of modern humans. Reclassification of Australopithecines that originally were split into either gracile or robust varieties has put the latter into a family of its own, *Paranthropus*. Taxonomists place humans, Australopithecines and related species in the same family as other great apes, in the Hominidae.

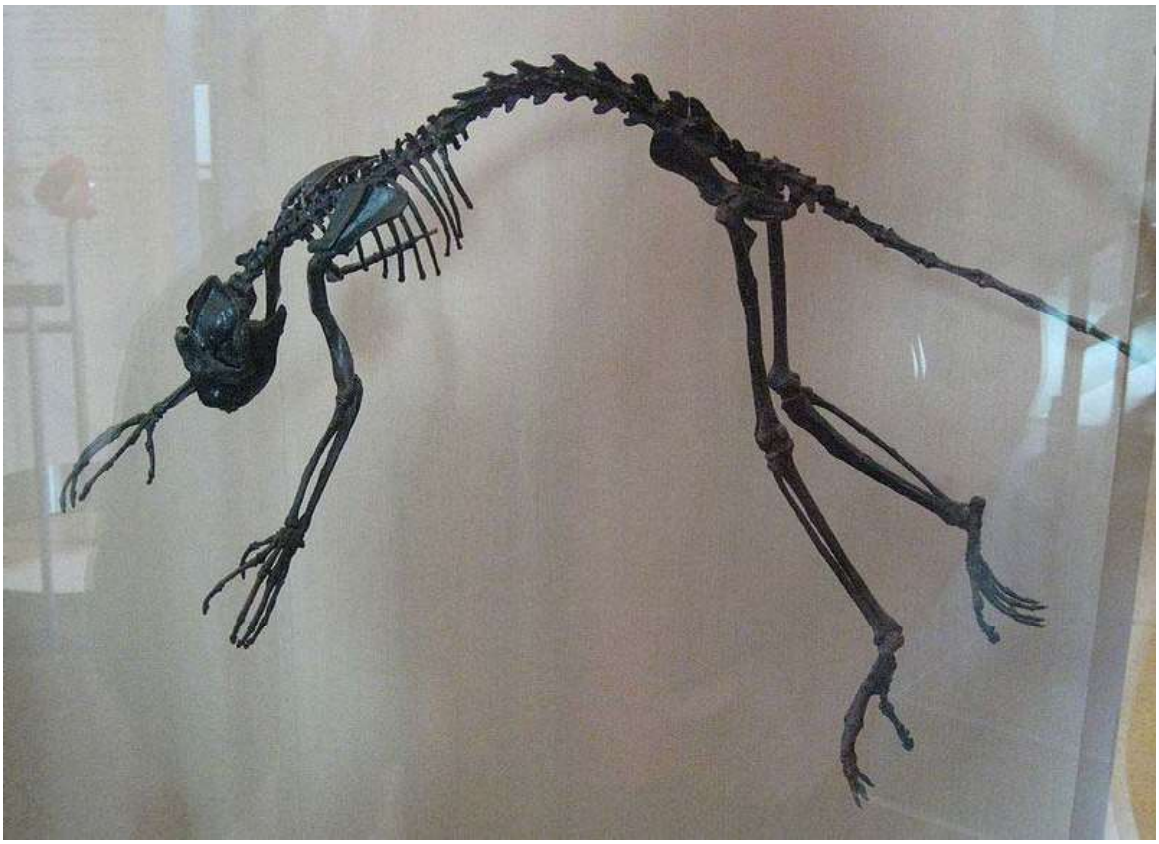
Before Homo

Evolution of the great apes



Plesiadapis

The evolutionary history of the primates can be traced back 65 million years, as one of the oldest of all surviving placental mammal groups. The oldest known primate-like mammal species, the Plesiadapis, come from North America, but they were widespread in Eurasia and Africa during the tropical conditions of the Paleocene and Eocene.



Notharctus

The beginning of modern climates was marked by the formation of the first Antarctic ice in the early Oligocene around 30 million years ago. A primate from this time was *Notharctus*. Fossil evidence found in Germany in the 1980s was determined to be about 16.5 million years old, some 1.5 million years older than similar species from East Africa and challenging the original theory regarding human ancestry originating on the African continent.

David Begun says that these primates flourished in Eurasia and that the lineage leading to the African apes and humans— including Dryopithecus—migrated south from Europe or Western Asia into Africa. The surviving tropical population, which is seen most completely in the upper Eocene and lowermost Oligocene fossil beds of the Fayum depression southwest of Cairo, gave rise to all living primates—lemurs of Madagascar, lorises of Southeast Asia, galagos or "bush babies" of Africa, and the anthropoids; platyrrhines or New World monkeys, and catarrhines or Old World monkeys and the great apes and humans.

The earliest known catarrhine is *Kamoyapithecus* from uppermost Oligocene at Eragaleit in the northern Kenya Rift Valley, dated to 24 million years ago. Its ancestry is generally thought to be species related to *Aegyptopithecus*, *Propliopithecus*, and *Parapithecus* from the Fayum, at around 35 million years ago. In 2010, *Saadanius* was described as a close relative of the last common ancestor of the crown catarrhines, and tentatively dated to 29–28 million years ago, helping to fill an 11-million-year gap in the fossil record.

Reconstructed tailless *Proconsul* skeleton

In the early Miocene, about 22 million years ago, the many kinds of arboreally adapted primitive catarrhines from East Africa suggest a long history of prior diversification. Fossils at 20 million years ago include fragments attributed to *Victoriapithecus*, the earliest Old World Monkey. Among the genera thought to be in the ape lineage leading up to 13 million years ago are *Proconsul*, *Rangwapithecus*, *Dendropithecus*, *Limnopithecus*, *Nacholapithecus*, *Equatorius*, *Nyanzapithecus*, *Afropithecus*, *Heliopithecus*, and *Kenyapithecus*, all from East Africa. The presence of other generalized non-cercopithecids of middle Miocene age from sites far distant—*Otavipithecus* from cave deposits in Namibia, and *Pierolapithecus* and *Dryopithecus* from France, Spain and Austria—is evidence of a wide diversity of forms across Africa and the Mediterranean basin during the relatively warm and equable climatic regimes of the early and middle Miocene. The youngest of the Miocene hominoids, *Oreopithecus*, is from 9 million year old coal beds in Italy.

Molecular evidence indicates that the lineage of gibbons (family Hylobatidae) became distinct from Great Apes between 18 and 12 million years ago, and that of orangutans (subfamily Ponginae) became distinct from the other Great Apes at about 12 million years; there are no fossils that clearly document the ancestry of gibbons, which may have originated in a so-far-unknown South East Asian hominoid population, but fossil proto-orangutans may be represented by *Ramapithecus* from India and *Griphopithecus* from Turkey, dated to around 10 million years ago.

Divergence of the human lineage from other Great Apes

Species close to the last common ancestor of gorillas, chimpanzees and humans may be represented by *Nakalipithecus* fossils found in Kenya and *Ouranopithecus* found in Greece. Molecular evidence suggests that between 8 and 4 million years ago, first the gorillas, and then the chimpanzees (genus *Pan*) split off from the line leading to the humans; human DNA is approximately 98.4% identical to that of chimpanzees when comparing single nucleotide polymorphisms. The fossil record of gorillas and chimpanzees is quite limited. Both poor preservation (rain forest soils tend to be acidic and dissolve bone) and sampling bias probably contribute to this problem.

Other hominines likely adapted to the drier environments outside the equatorial belt, along with antelopes, hyenas, dogs, pigs, elephants, and horses. The equatorial belt contracted after about 8 million years ago. Fossils of these hominans - the species in the human lineage following divergence from the chimpanzees - are relatively well known.

The earliest are *Sahelanthropus tchadensis* (7 Ma) and *Orrorin tugenensis* (6 Ma), followed by:

- *Ardipithecus* (5.5–4.4 Ma), with species *Ar. kadabba* and *Ar. ramidus*;
- *Australopithecus* (4–1.8 Ma), with species *Au. anamensis*, *Au. afarensis*, *Au. africanus*, *Au. bahrelghazali*, *Au. garhi*, and *Au. sediba*;
- *Kenyanthropus* (3–2.7 Ma), with species *Kenyanthropus platyops*;
- *Paranthropus* (3–1.2 Ma), with species *P. aethiopicus*, *P. boisei*, and *P. robustus*;
- *Homo* (2 Ma–present), with species *Homo habilis*, *Homo rudolfensis*, *Homo ergaster*, *Homo georgicus*, *Homo antecessor*, *Homo cepranensis*, *Homo erectus*, *Homo heidelbergensis*, *Homo rhodesiensis*, *Homo neanderthalensis*, *Homo sapiens idaltu*, *Archaic Homo sapiens*, *Homo floresiensis*.

Genus Homo

Homo sapiens is the only extant species of its genus, *Homo*. While some other, extinct, *Homo* species might have been ancestors of *Homo sapiens*, many were likely our "cousins", having speciated away from our ancestral line. There is not yet a consensus as to which of these groups should count as separate species and which as subspecies. In some cases this is due to the dearth of fossils, in other cases it is due to the slight differences used to classify species in the *Homo* genus. The Sahara pump theory

(describing an occasionally passable "wet" Sahara Desert) provides an explanation of the early variation in the genus *Homo*.

Based on archaeological and paleontological evidence, it has been possible to infer, to some extent, the ancient dietary practices of various *Homo* species and to study the role of diet in physical and behavioral evolution within *Homo*.

H. habilis and *H. gautengensis*

Homo habilis lived from about 2.4 to 1.4 Ma. *Homo habilis* evolved in South and East Africa in the late Pliocene or early Pleistocene, 2.5–2 Ma, when it diverged from the Australopithecines. *Homo habilis* had smaller molars and larger brains than the Australopithecines, and made tools from stone and perhaps animal bones. One of the first known hominids, it was nicknamed 'handy man' by its discoverer, Louis Leakey due to its association with stone tools. Some scientists have proposed moving this species out of *Homo* and into *Australopithecus* due to the morphology of its skeleton being more adapted to living on trees rather than to moving on two legs like *Homo sapiens*.

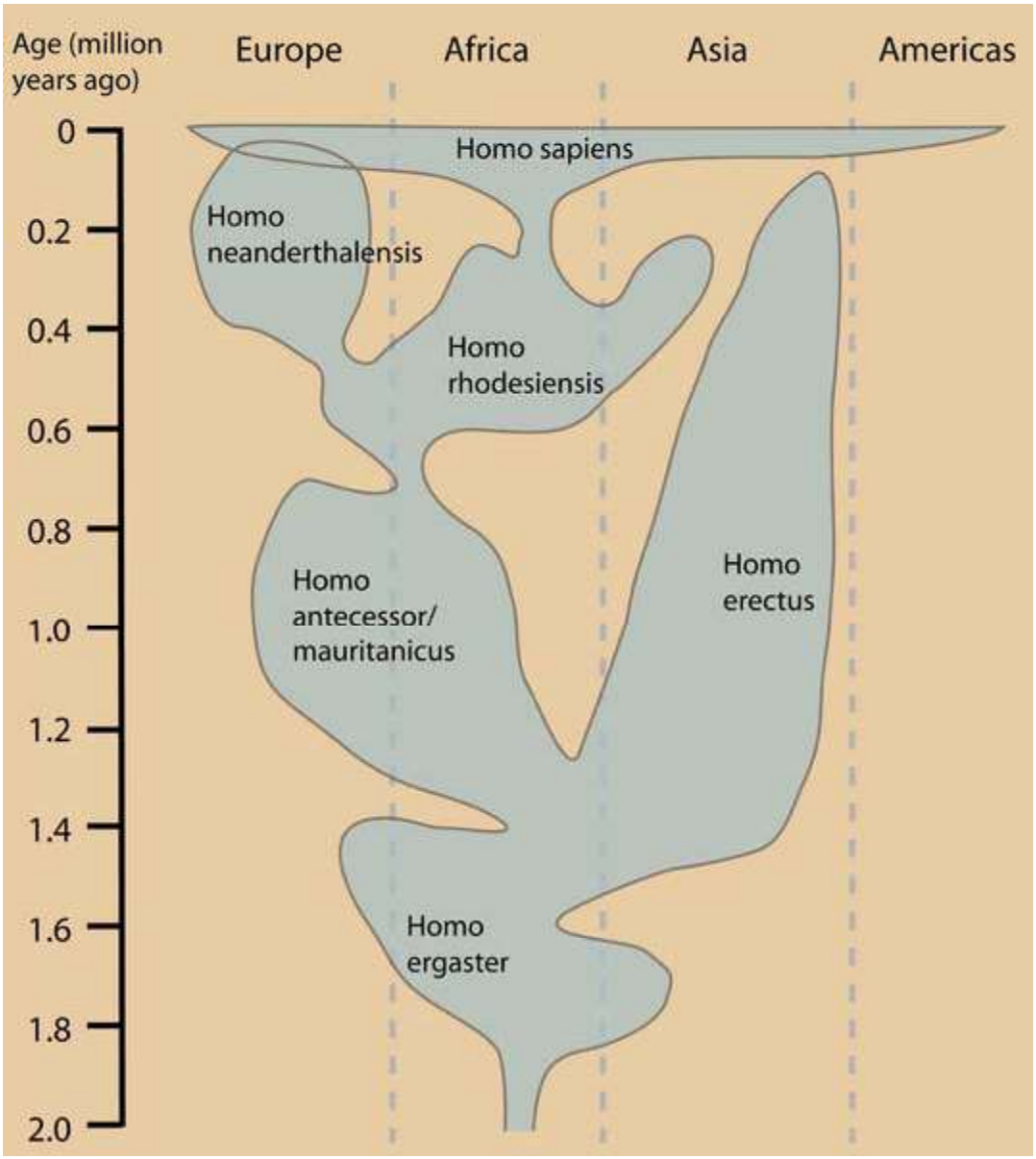
It was considered to be the first species of the genus *Homo* until May 2010, when a new species, *Homo gautengensis* was discovered in South Africa, that most likely arose earlier than *Homo habilis*.

H. rudolfensis and *H. georgicus*

These are proposed species names for fossils from about 1.9–1.6 Ma, the relation of which with *Homo habilis* is not yet clear.

- *Homo rudolfensis* refers to a single, incomplete skull from Kenya. Scientists have suggested that this was another *Homo habilis*, but this has not been confirmed.
- *Homo georgicus*, from Georgia, may be an intermediate form between *Homo habilis* and *Homo erectus*, or a sub-species of *Homo erectus*.

H. ergaster and *H. erectus*



One current view of the temporal and geographical distribution of hominid populations. Other interpretations differ mainly in the taxonomy and geographical distribution of hominid species.

The first fossils of *Homo erectus* were discovered by Dutch physician Eugene Dubois in 1891 on the Indonesian island of Java. He originally gave the material the name *Pithecanthropus erectus* based on its morphology that he considered to be intermediate between that of humans and apes. *Homo erectus* (H erectus) lived from about 1.8 Ma to about 70,000 years ago (which would indicate that they were probably wiped out by the Toba catastrophe; however, *Homo erectus soloensis* and *Homo floresiensis* survived it). Often the early phase, from 1.8 to 1.25 Ma, is considered to be a separate species, *Homo*

ergaster, or it is seen as a subspecies of *Homo erectus*, *Homo erectus ergaster*. In the early Pleistocene, 1.5–1 Ma, in Africa, Asia, and Europe, some populations of *Homo habilis* are thought to have evolved larger brains and made more elaborate stone tools; these differences and others are sufficient for anthropologists to classify them as a new species, *Homo erectus*. In addition *Homo erectus* was the first human ancestor to walk truly upright. This was made possible by the evolution of locking knees and a different location of the foramen magnum (the hole in the skull where the spine enters). They may have used fire to cook their meat.

A famous example of *Homo erectus* is Peking Man; others were found in Asia (notably in Indonesia), Africa, and Europe. Many paleoanthropologists now use the term *Homo ergaster* for the non-Asian forms of this group, and reserve *Homo erectus* only for those fossils that are found in Asia and meet certain skeletal and dental requirements which differ slightly from *H. ergaster*.

H. cepranensis and *H. antecessor*

These are proposed as species that may be intermediate between *H. erectus* and *H. heidelbergensis*.

- *H. antecessor* is known from fossils from Spain and England that are dated 1.2 Ma–500 ka.
- *H. cepranensis* refers to a single skull cap from Italy, estimated to be about 800,000 years old.

H. heidelbergensis

H. heidelbergensis (Heidelberg Man) lived from about 800,000 to about 300,000 years ago. Also proposed as *Homo sapiens heidelbergensis* or *Homo sapiens paleohungaricus*.

H. rhodesiensis, and the Gawis cranium

- *H. rhodesiensis*, estimated to be 300,000–125,000 years old. Most current experts believe Rhodesian Man to be within the group of *Homo heidelbergensis*, though other designations such as Archaic Homo sapiens and Homo sapiens rhodesiensis have also been proposed.
- In February 2006 a fossil, the Gawis cranium, was found which might possibly be a species intermediate between *H. erectus* and *H. sapiens* or one of many evolutionary dead ends. The skull from Gawis, Ethiopia, is believed to be 500,000–250,000 years old. Only summary details are known, and no peer reviewed studies have been released by the finding team. Gawis man's facial features suggest its being either an intermediate species or an example of a "Bodo man" female.

H. neanderthalensis

Le Ferrassie Neanderthal skull (cast)

H. neanderthalensis lived from 400,000 to about 30,000 years ago. Also proposed as *Homo sapiens neanderthalensis*. Evidence from sequencing mitochondrial DNA indicated that no significant gene flow occurred between *H. neanderthalensis* and *H. sapiens*, and, therefore, the two were separate species that shared a common ancestor about 660,000 years ago. In 1997, Mark Stoneking stated: "These results [based on mitochondrial DNA extracted from Neanderthal bone] indicate that Neanderthals did not contribute mitochondrial DNA to modern humans… Neanderthals are not our ancestors". Subsequent investigation of a second source of Neanderthal DNA supported these findings.

However, the 2010 sequencing of the Neanderthal genome indicated that Neanderthals did indeed interbreed with *H. sapiens circa* 75,000 BC (after *H. sapiens* moved out from Africa, but before they separated into Europe, the Middle East, and Asia). Nearly all modern humans have 1% to 4% of their DNA derived from Neanderthal DNA. This 1–4% bit of DNA is only present in non-African humans. However, supporters of the multiregional hypothesis point to recent studies indicating non-African nuclear DNA

heritage dating to one Ma, although the reliability of these studies has been questioned. Competition from *Homo sapiens* probably contributed to Neanderthal extinction. They could have coexisted in Europe for as long as 10,000 years.

H. sapiens

H. sapiens (the adjective *sapiens* is Latin for "wise" or "intelligent") have lived from about 250,000 years ago to the present. Between 400,000 years ago and the second interglacial period in the Middle Pleistocene, around 250,000 years ago, the trend in skull expansion and the elaboration of stone tool technologies developed, providing evidence for a transition from *H. erectus* to *H. sapiens*. The direct evidence suggests there was a migration of *H. erectus* out of Africa, then a further speciation of *H. sapiens* from *H. erectus* in Africa. A subsequent migration within and out of Africa eventually replaced the earlier dispersed *H. erectus*. This migration and origin theory is usually referred to as the *recent single origin* or Out of Africa theory. Current evidence does not preclude some multiregional evolution or some admixture of the migrant *H. sapiens* with existing *Homo* populations. This is a hotly debated area of paleoanthropology.

Current research has established that humans are genetically highly homogenous; that is, the DNA of individuals is more alike than usual for most species, which may have resulted from their relatively recent evolution or the possibility of a population bottleneck resulting from cataclysmic natural events such as the Toba catastrophe. Distinctive genetic characteristics have arisen, however, primarily as the result of small groups of people moving into new environmental circumstances. These adapted traits are a very small component of the *Homo sapiens* genome, but include various characteristics such as skin color and nose form, in addition to internal characteristics such as the ability to breathe more efficiently at high altitudes.

H. sapiens idaltu, from Ethiopia, is an extinct sub-species who lived about 160,000 years ago.

H. floresiensis

H. floresiensis, which lived from approximately 100,000 to 12,000 before present, has been nicknamed *hobbit* for its small size, possibly a result of insular dwarfism. *H. floresiensis* is intriguing both for its size and its age, being a concrete example of a recent species of the genus *Homo* that exhibits derived traits not shared with modern humans. In other words, *H. floresiensis* share a common ancestor with modern humans, but split from the modern human lineage and followed a distinct evolutionary path. The main find was a skeleton believed to be a woman of about 30 years of age. Found in 2003 it has been dated to approximately 18,000 years old. The living woman was estimated to be one meter in height, with a brain volume of just 380 cm^3 (considered small for a chimpanzee and less than a third of the *H. sapiens* average of 1400 cm^3).

However, there is an ongoing debate over whether *H. floresiensis* is indeed a separate species. Some scientists presently believe that *H. floresiensis* was a modern *H. sapiens*

suffering from pathological dwarfism. This hypothesis is supported in part, because some modern humans who live on Flores, the island where the skeleton was found, are pygmies. This coupled with pathological dwarfism, it is argued, could indeed create a hobbit-like human. The other major attack on *H. floresiensis* is that it was found with tools only associated with *H. sapiens*.

The hypothesis of pathological dwarfism, however, fails to explain additional anatomical features that are unlike those of modern humans (diseased or not) but much like those of ancient members of our genus. Aside from cranial features, these features include the form of bones in the wrist, forearm, shoulder, knees, and feet.

Denisova hominin

In 2008, archaeologists working at the site of Denisova Cave in the Altai Mountains of Siberia uncovered a small bone fragment from the fifth finger of a juvenile hominin, dubbed the "X-woman" (referring to the maternal descent of mitochondrial DNA), or the Denisova hominin. Artifacts, including a bracelet, excavated in the cave at the same level were carbon dated to around 40,000 BP. As DNA had survived in the fossil fragment due to the cool climate of the Denisova Cave, a team of scientists from the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany sequenced mtDNA extracted from the fragment.

The analysis indicated that modern humans, Neanderthals, and the Denisova hominin last shared a common ancestor around 1 million years ago. Modern humans are known to have overlapped with Neanderthals in Europe for more than 10,000 years, and the discovery raises the possibility that Neanderthals, modern humans and the Denisovan hominin may have co-existed together.

The DNA analysis further indicated that this new hominin species was the result of an early migration out of Africa, distinct from the later out-of-Africa migrations associated with Neanderthals and modern humans, but also distinct from the earlier African exodus of *Homo erectus*. Professor Chris Stringer, human origins researcher at London's Natural History Museum and one of the leading proponents of the recent single-origin hypothesis, remarked: "This new DNA work provides an entirely new way of looking at the still poorly understood evolution of humans in central and eastern Asia." Pääbo noted that the existence of this distant branch creates a much more complex picture of humankind during the Late Pleistocene.

Comparative table of *Homo* species

Comparative table of *Homo* species

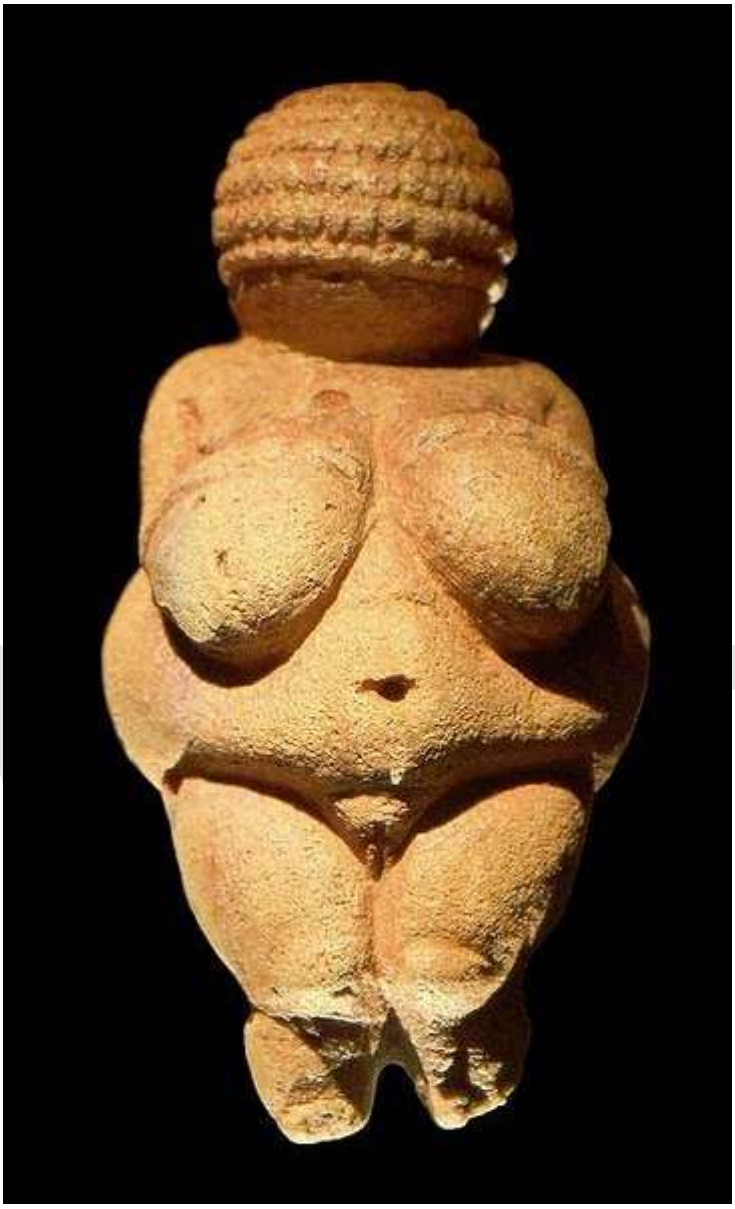
Species	Lived when (Ma)	Lived where	Adult height	Adult mass	Cranial capacity (cm³)	Fossil record	Discovery / publication of name
H. antecessor	1.2 – 0.8	Spain	1.75 m (5.7 ft)	90 kg (200 lb)	1,000	2 sites	1997
H. cepranensis	0.9 – 0.8?	Italy			1,000	1 skull cap	1994/2003
H. erectus	1.5 – 0.2	Africa, Eurasia (Java, China, India, Caucasus)	1.8 m (5.9 ft)	60 kg (130 lb)	850 (early) – 1,100 (late)	Many	1891/1892
H. ergaster	1.9 – 1.4	Eastern and Southern Africa	1.9 m (6.2 ft)		700–850	Many	1975
H. floresiensis	0.10? – 0.012	Indonesia	1.0 m (3.3 ft)	25 kg (55 lb)	400	7 individuals	2003/2004
H. gautengensis	>2 – 0.6	South Africa	1.0 m (3.3 ft)			1 individual	2010/2010
H. georgicus	1.8	Georgia			600	4 individuals	1999/2002
H. habilis	2.3 – 1.4	Africa	1.0–1.5 m (3.3–4.9 ft)	33–55 kg (73–120 lb)	510–660	Many	1960/1964
H. heidelbergensis	0.6 – 0.35	Europe, Africa, China	1.8 m (5.9 ft)	60 kg (130 lb)	1,100–1,400	Many	1908
H. neanderthalensis	0.35 – 0.03	Europe, Western Asia	1.6 m (5.2 ft)	55–70 kg (120–150 lb) (heavily built)	1,200–1,900	Many	(1829)/1864
H. rhodesiensis	0.3 – 0.12	Zambia			1,300	Very few	1921
H. rudolfensis	1.9	Kenya				1 skull	1972/1986
H. sapiens idaltu	0.16 – 0.15	Ethiopia			1,450	3 craniums	1997/2003
H. sapiens sapiens (modern humans)	0.2 – present	Worldwide	1.4–1.9 m (4.6–6.2 ft)	50–100 kg (110–220 lb)	1,000–1,850	Still living	—/1758

Use of tools

"A sharp rock", an Oldowan pebble tool, the most basic of human stone tools

Fire, one of the greatest human discoveries

An Acheulean hand axe, the pinnacle of *Homo erectus* stone working



Venus of Willendorf, an example of Paleolithic art

Using tools has been interpreted as a sign of intelligence, and it has been theorized that tool use may have stimulated certain aspects of human evolution—most notably the continued expansion of the human brain. Paleontology has yet to explain the expansion of this organ over millions of years despite being extremely demanding in terms of energy consumption. The brain of a modern human consumes about 20 watts (400 kilocalories per day), which is one fifth of the energy consumption of a human body. Increased tool use would allow hunting for energy-rich meat products, and would enable processing more energy-rich plant products. Researchers have suggested that early hominids were thus under evolutionary pressure to increase their capacity to create and use tools.

Precisely when early humans started to use tools is difficult to determine, because the more primitive these tools are (for example, sharp-edged stones) the more difficult it is to decide whether they are natural objects or human artifacts. There is some evidence that the australopithecines (4 Ma) may have used broken bones as tools, but this is debated.

It should be noted that many species make and use tools, but it is the human species that dominates the areas of making and using more complex tools. The oldest known tools are the "Oldowan stone tools" from Ethiopia. It was discovered that these tools are from 2.5 to 2.6 million years old, which predates the earliest known "Homo" species. There is no known evidence that any "Homo" specimens appeared by 2.5 Ma. A Homo fossil was found near some Oldowan tools, and its age was noted at 2.3 million years old, suggesting that maybe the Homo species did indeed create and use these tools. It is surely possible, but not solid evidence. Bernard Wood noted that "Paranthropus" coexisted with the early Homo species in the area of the "Oldowan Industrial Complex" over roughly the same span of time. Although there is no direct evidence that points to Paranthropus as the tool makers, their anatomy lends to indirect evidence of their capabilities in this area. Most paleoanthropologists agree that the early "Homo" species were indeed responsible for most of the Oldowan tools found. They argue that when most of the Oldowan tools were found in association with human fossils, Homo was always present, but Paranthropus was not.

In 1994, Randall Susman used the anatomy of opposable thumbs as the basis for his argument that both the Homo and Paranthropus species were toolmakers. He compared bones and muscles of human and chimpanzee thumbs, finding that humans have 3 muscles that chimps lack. Humans also have thicker metacarpals with broader heads, making the human hand more successful at precision grasping than the chimpanzee hand. Susman defended that modern anatomy of the human thumb is an evolutionary response to the requirements associated with making and handling tools and that both species were indeed toolmakers.

Stone tools

Stone tools are first attested around 2.6 Ma, when *H. habilis* in Eastern Africa used so-called pebble tools, choppers made out of round pebbles that had been split by simple strikes. This marks the beginning of the Paleolithic, or Old Stone Age; its end is taken to be the end of the last Ice Age, around 10,000 years ago. The Paleolithic is subdivided into the Lower Paleolithic (Early Stone Age, ending around 350,000–300,000 years ago), the Middle Paleolithic (Middle Stone Age, until 50,000–30,000 years ago), and the Upper Paleolithic.

The period from 700,000–300,000 years ago is also known as the Acheulean, when *H. ergaster* (or *erectus*) made large stone hand-axes out of flint and quartzite, at first quite rough (Early Acheulian), later "retouched" by additional, more subtle strikes at the sides of the flakes. After 350,000 BP (Before Present) the more refined so-called Levallois technique was developed. It consisted of a series of consecutive strikes, by which scrapers, slicers ("racloirs"), needles, and flattened needles were made. Finally, after

about 50,000 BP, ever more refined and specialized flint tools were made by the Neanderthals and the immigrant Cro-Magnons (knives, blades, skimmers). In this period they also started to make tools out of bone.

Modern humans and the "Great Leap Forward" debate

Until about 50,000–40,000 years ago the use of stone tools seems to have progressed stepwise. Each phase (*H. habilis*, *H. ergaster*, *H. neanderthalensis*) started at a higher level than the previous one, but once that phase started further development was slow. These *Homo* species were culturally conservative, but after 50,000 BC modern human culture started to change at a much greater speed. Jared Diamond, author of *The Third Chimpanzee*, and some anthropologists characterize this as a "Great Leap Forward".

Modern humans started burying their dead, making clothing out of hides, developing sophisticated hunting techniques (such as using trapping pits or driving animals off cliffs), and engaging in cave painting. As human culture advanced, different populations of humans introduced novelty to existing technologies: artifacts such as fish hooks, buttons and bone needles show signs of variation among different populations of humans, something that had not been seen in human cultures prior to 50,000 BP. Typically, *H. neanderthalensis* populations do not vary in their technologies.

Among concrete examples of Modern human behavior, anthropologists include specialization of tools, use of jewellery and images (such as cave drawings), organization of living space, rituals (for example, burials with grave gifts), specialized hunting techniques, exploration of less hospitable geographical areas, and barter trade networks. Debate continues as to whether a "revolution" led to modern humans ("the big bang of human consciousness"), or whether the evolution was more gradual.

Models of human evolution

Today, all humans belong to one population of *Homo sapiens sapiens,* undivided by species barrier. However, according to the "Out of Africa" model this is not the first species of hominids: the first species of genus *Homo*, *Homo habilis*, evolved in East Africa at least 2 Ma, and members of this species populated different parts of Africa in a relatively short time. *Homo erectus* evolved more than 1.8 Ma, and by 1.5 Ma had spread throughout the Old World.

Anthropologists have been divided as to whether current human population evolved as one interconnected population (as postulated by the Multiregional Evolution hypothesis), or evolved only in East Africa, speciated, then migrated out of Africa and replaced human populations in Eurasia (called the "Out of Africa" Model or the "Complete Replacement" Model).

Multiregional model

Multiregional evolution, a *model to account for the pattern of human evolution*, was proposed by Milford H. Wolpoff in 1988. Multiregional evolution holds that human evolution from the beginning of the Pleistocene 2.5 million years BP to the present day has been within a single, continuous human species, evolving worldwide to modern *Homo sapiens*.

According to the multiregional hypothesis, fossil and genomic data are evidence for worldwide human evolution and contradict the recent speciation postulated by the Recent African origin hypothesis. The fossil evidence was insufficient for Richard Leakey to resolve this debate. Studies of haplogroups in Y-chromosomal DNA and mitochondrial DNA have largely supported a recent African origin. Evidence from autosomal DNA also supports the Recent African origin. However the presence of archaic admixture in modern humans remains a possibility and has been suggested by some studies.

Out of Africa

According to the Out of Africa model, developed by Chris Stringer and Peter Andrews, modern *H. sapiens* evolved in Africa 200,000 years ago. *Homo sapiens* began migrating from Africa between 70,000 – 50,000 years ago and eventually replaced existing hominid species in Europe and Asia. Out of Africa has gained support from research using mitochondrial DNA (mtDNA). After analysing genealogy trees constructed using 133 types of mtDNA, researchers concluded that all were descended from a woman from Africa, dubbed Mitochondrial Eve. Out of Africa is also supported by the fact that mitochondrial genetic diversity is highest among African populations.

There are differing theories on whether there was a single exodus or several. A multiple dispersal model involves the Southern Dispersal theory, which has gained support in recent years from genetic, linguistic and archaeological evidence. In this theory, there was a coastal dispersal of modern humans from the Horn of Africa around 70,000 years ago. This group helped to populate Southeast Asia and Oceania, explaining the discovery of early human sites in these areas much earlier than those in the Levant. A second wave of humans dispersed across the Sinai peninsula into Asia, resulting in the bulk of human population for Eurasia. This second group possessed a more sophisticated tool technology and was less dependent on coastal food sources than the original group. Much of the evidence for the first group's expansion would have been destroyed by the rising sea levels at the end of the Holocene era. The multiple dispersal model is contradicted by studies indicating that the populations of Eurasia and the populations of Southeast Asia and Oceania are all descended from the same mitochondrial DNA lineages, which support a single migration out of Africa that gave rise to all non-African populations.

The broad study of African genetic diversity headed by Dr. Sarah Tishkoff found the San people to express the greatest genetic diversity among the 113 distinct populations sampled, making them one of 14 "ancestral population clusters". The research also

located the origin of modern human migration in south-western Africa, near the coastal border of Namibia and Angola.

According to the Toba catastrophe theory to which some anthropologists and archeologists subscribe, the supereruption of Lake Toba on Sumatra island in Indonesia roughly 70,000 years ago had global consequences, killing most humans then alive and creating a population bottleneck that affected the genetic inheritance of all humans today.

Recent and current human evolution

Natural selection is being observed in contemporary human populations, with recent findings demonstrating the population which is at risk of the severe debilitating disease kuru has significant over-representation of an immune variant of the prion protein gene G127V versus non-immune alleles. Scientists postulate one of the reasons for the rapid selection of this genetic variant is the lethality of the disease in non-immune persons. Other reported evolutionary trends in other populations include a lengthening of the reproductive period, reduction in cholesterol levels, blood glucose and blood pressure.

In their 2009 book *The 10,000 Year Explosion*, Gregory Cochran and Henry Harpending argue that human evolution has accelerated since and as a result of the development of agriculture and civilisation since some 50,000 years ago, and that there are consequently substantial genetic differences between different current human populations.

Genetics

Human evolutionary genetics studies how one human genome differs from the other, the evolutionary past that gave rise to it, and its current effects. Differences between genomes have anthropological, medical and forensic implications and applications. Genetic data can provide important insight into human evolution.

Notable human evolution researchers

- Robert Broom, a Scottish physician and palaeontologist whose work on South Africa led to the discovery and description of the Paranthropus genus of hominins, and of "Mrs. Ples"
- Raymond Dart, an Australian anatomist and palaeoanthropologist, whose work at Taung, in South Africa, led to the discovery of *Australopithecus africanus*
- Charles Darwin, a British naturalist who documented considerable evidence that species originate through evolutionary change
- Henry McHenry, an American anthropologist who specializes in studies of human evolution, the origins of bipedality, and paleoanthropology
- Donald Johanson, credited with the discovery of *Australopithecus afarensis*
- Jeffrey Laitman, an American anatomist and physical anthropologist whose work has explored the evolution of the vocal tract and speech
- Louis Leakey, an African archaeologist and naturalist whose work was important in establishing human evolutionary development in Africa

- Mary Leakey, a British archaeologist and anthropologist whose discoveries in
  - Africa include the Laetoli footprints
- Richard Leakey, an African paleontologist and archaeologist, son of Louis and Mary Leakey
- Svante Pääbo, a Swedish biologist specializing in evolutionary genetics
- David Pilbeam, a paleoanthropologist, researcher and writer on a range of topics involving human and primate evolution.
- Jeffrey H. Schwartz, an American physical anthropologist and professor of biological anthropology
- Chris Stringer, anthropologist, leading proponent of the recent single origin hypothesis
- Alan Templeton, geneticist and statistician, proponent of the multiregional hypothesis
- Philip V. Tobias, a South African palaeoanthropologist is one of the world's leading authorities on the evolution of humankind
- Erik Trinkaus, a prominent American paleoanthropologist and expert on Neanderthal biology and human evolution
- Milford H. Wolpoff, an American paleoanthropologist who is the leading proponent of the multiregional evolution hypothesis.

Chapter- 3

Evolution of Mammalian Auditory Ossicles

The **evolution of mammalian auditory ossicles** is one of the most well-documented and important evolutionary events, demonstrating both numerous transitional forms as well as an excellent example of exaptation, the re-purposing of existing structures during evolution.

In reptiles, the eardrum is connected to the inner ear via a single bone, the stapes or stirrup, while the upper and lower jaws contain several bones not found in mammals. Over the course of the evolution of mammals, one lower and one upper jaw bone (the articular and quadrate) lost their purpose in the jaw joint and were put to new use in the middle ear, connecting to the stapes and forming a chain of three bones (collectively called the ossicles) which amplify sounds and allow more acute hearing. In mammals, these three bones are known as the malleus, incus, and stapes (hammer, anvil, and stirrup respectively).

The evidence that the malleus and incus are homologous to the reptilian articular and quadrate was originally embryological, and since this discovery an abundance of transitional fossils has both supported the conclusion and given a detailed history of the transition. The evolution of the stapes was an earlier and distinct event.

Reichert–Gaupp theory

The relationship between the reptilian jaw bones and mammalian middle-ear bones was first established on the basis of embryology and comparative anatomy by Reichert (in 1837, before the publication of On the Origin of Species in 1859) and advanced by Gaupp, and this is known as the *Reichert–Gaupp Theory*.

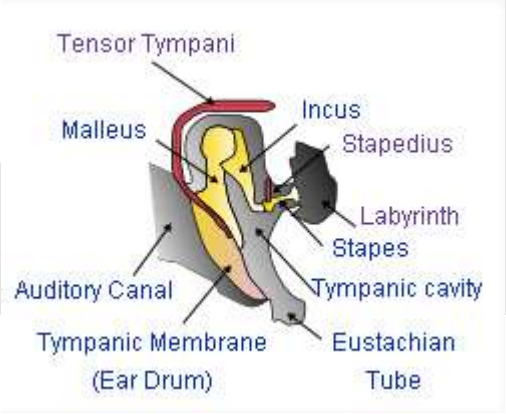
In the course of the development of the embryo, the incus and malleus arise from the same First Pharyngeal arch as the Mandible and Maxilla, and are served by mandibular and maxillary division of the Trigeminal Cranial nerve.

...the discovery that the mammalian malleus and incus were actually homologues of visceral elements of the "reptilian" jaw articulation ... ranks as one of the milestones in the history of comparative biology.

... it is one of the triumphs of the long series of researches on the extinct Theromorph reptiles, begun by Owen (1845), and continued by Seeley, Broom, and Watson, to have revealed the intermediate steps by which the change may have occurred from an inner quadrate to an outer squamosal articulation ...

There are also more recent studies in the genetic basis for the development of the ossicles from the embryonic arch. and relating this to evolutionary history.

"*Bapx1*, also known as *Nkx3.2*, is the vertebrate homologue of the *Drosophila* gene *Bagpipe*. A member of the NK2 class of homeobox genes ..." and this gene is implicated in the change from the jaw bones of non-mammals to the ossicles of mammals. Yet the transition between the "reptilian" jaw and the "mammalian" inner ear was not bridged in the fossil record until the 1950s with the elaboration of such fossils as the now-famous *Morganucodon*.



A typical mammalian middle ear: sound makes the tympanum (ear-drum) vibrate; 3 small bones, the malleus, incus and stapes, transmit the vibrations to the Labyrinth (inner ear), which transforms the vibrations into nerve signals.

Definitive mammalian middle ear

The mammalian middle ear contains three tiny bones known as the ossicles: malleus, incus, and stapes. The ossicles are a complex system of levers whose functions include: reducing the amplitude of the vibrations; increasing the amount of energy transmitted. The details of these effects vary noticeably between different mammal species, even when the species are as closely related as humans and chimpanzees.

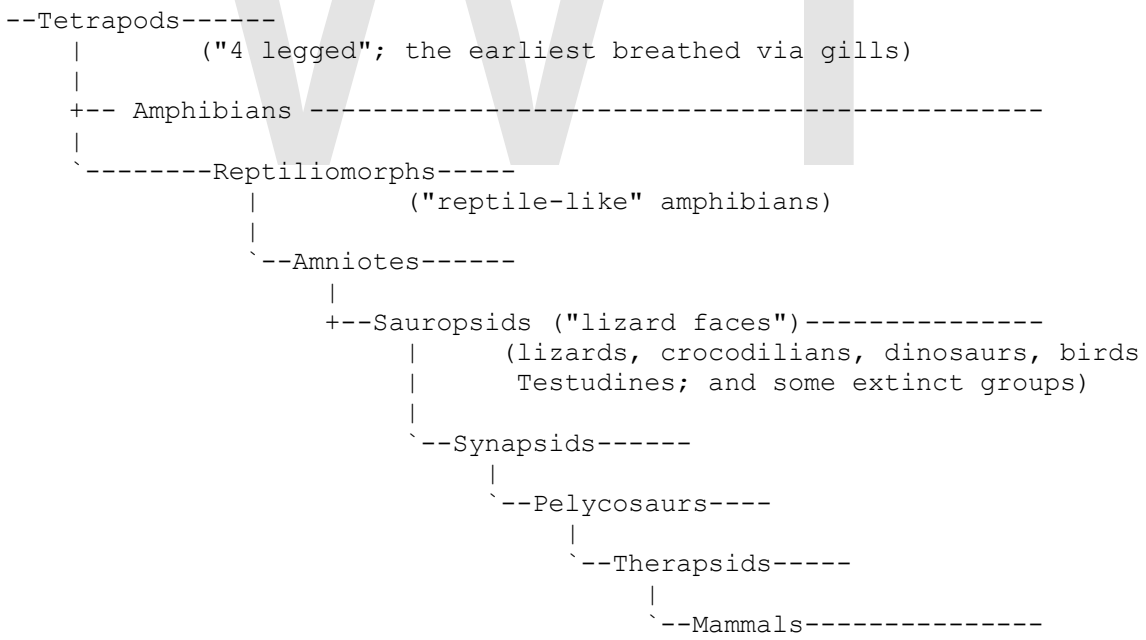
Evolutionary history

Definition of "mammal"

Living mammal species can be identified by the presence in females of mammary glands which produce milk. Other features are required when classifying fossils, since mammary glands and other soft-tissue features are not visible in fossils. Paleontologists therefore use a distinguishing feature that is shared by all living mammals (including monotremes), but is not present in any of the early Triassic therapsids ("mammal-like reptiles"): mammals use two bones for hearing that all other amniotes use for eating. The earliest amniotes had a jaw joint composed of the articular (a small bone at the back of the lower jaw) and the quadrate (a small bone at the back of the upper jaw). All non-mammalian amniotes use this system including lizards, crocodilians, dinosaurs (and their descendants the birds) and therapsids; so the only ossicle in their middle ears is the stapes. But mammals have a different jaw joint, composed only of the dentary (the lower jaw bone which carries the teeth) and the squamosal (another small skull bone). And in mammals the quadrate and articular bones have become the incus and malleus bones in the middle ear.

Summary of the fossil evidence

Here is a very simplified "family tree" of the various lineages involved:

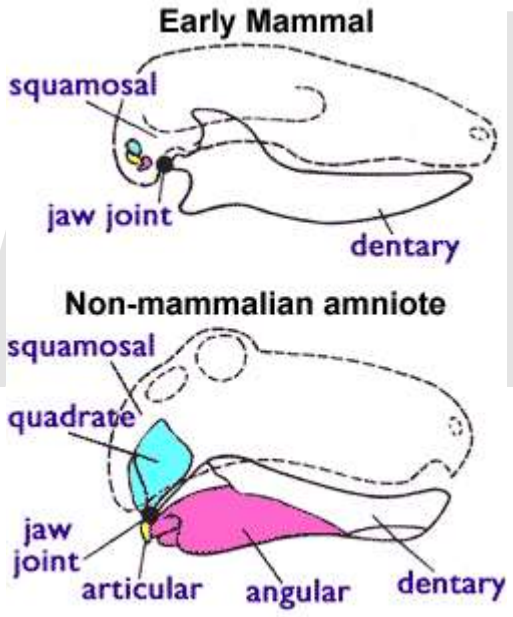


The first fully terrestrial vertebrates were amniotes - their eggs had internal membranes which allowed the developing embryo to breathe but kept water in. This allowed amniotes to lay eggs on dry land, while amphibians generally need to lay their eggs in water. The first amniotes apparently arose in the late Carboniferous from the ancestral reptiliomorphs (a group of amphibians whose only living descendants are amniotes).

Within a few million years two important amniote lineages became distinct: mammals' synapsid ancestors and the sauropsids, from which lizards, snakes, crocodilians, dinosaurs and birds are descended.

The earliest known fossils of all these groups date from about 320 to 315M years ago. Unfortunately it is difficult to be sure about when each of them evolved, since vertebrate fossils from the late Carboniferous are very rare, and therefore the actual first occurrences of each of these types of animal might have been considerably earlier.

The pattern in most of the following sections is that each successive more "advanced" group started with the more "primitive" jaws and ears of its predecessors, then developed more mammal-like jaws and ears, and so on. The evolution of mammalian jaw joints and ears did not proceed neatly in step with the evolution of other mammalian features; or, to put it another way, all but the last of the various stages into which paleontologists divide the evolution towards the mammalian condition are not defined by their jaw joints and ears.



Mammalian and non-mammalian jaws. In the mammal configuration, the quadrate and articular bones are much smaller and form part of the middle ear. Note that in mammals the lower jaw consists of only the dentary bone.

Early tetrapod and amniote ears

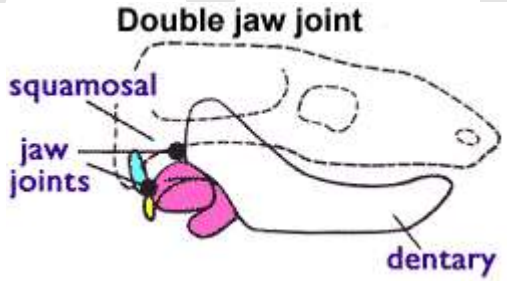
In modern amniotes (including mammals), the middle ear collects airborne sounds through an ear drum and transmits the vibrations to the inner ear via thin cartilaginous and ossified structures, which usually include the stapes (a stirrup-shaped auditory ossicle). But the earliest tetrapods, amphibians and amniotes probably did not have ear drums. In fact ear drums apparently evolved independently three to six times, in:

stegocephalians (very primitive amphibians); in anurans (the amphibian group that includes frogs and toads); in synapsids (mammals and their extinct relatives), in diapsids (the most important sauropsid group, including lizards, crocodiles, dinosaurs and birds); perhaps separately in anapsids (turtles and their extinct relatives), if turtles are not modified diapsids; probably in seymouriamorphs (a group of reptiliomorphs); and possibly in some temnospondyls (primitive amphibians). In all basal members of the 3 major clades of amniotes (synapsids, eureptiles, and parareptiles) the stapes bones are relatively massive props that support the braincase, and this function prevents them from being used as part of the hearing system. But there is increasing evidence that synapsids, eureptiles and parareptiles developed eardrums connected to the inner ear by stapes during the Permian.

Early therapsid jaws and ears

The jaws of early synapsids, including the ancestors of mammals, were similar to those of other tetrapods of the time, with a lower jaw consisting of a tooth-bearing dentary bone and several smaller posterior bones. The jaw joint consisted of the articular bone in the lower jaw and the quadrate in the upper jaw. The early pelycosaurs (late Carboniferous and early Permian) most probably did not have tympanic membranes (external eardrums), and their massive stapes bones supported the braincase, with the lower ends resting on the quadrates. But their descendants the therapsids (including mammals' ancestors) probably did have tympanic membranes and these probably were in contact with the quadrate bones; and the stapes bones were still in contact with the quadrates but functioned as auditory ossicles rather than braincase supports; so the therapsids' quadrates had a dual function, as part of the jaw joint and as parts of the hearing system.

Twin-jointed jaws



Morganucodontidae and other transitional forms had both types of jaw joint: dentary-squamosal (front) and articular-quadrate (rear).

During the Permian and early Triassic the dentary of therapsids, including the ancestors of mammals, continually enlarged while other jaw bones were reduced. Eventually, the dentary was able to make contact with the squamosal, a bone in the upper jaw located anterior to the quadrate, allowing two simultaneous jaw joints - an anterior "mammalian" joint between the dentary and squamosal and a posterior "reptilian" joint between the quadrate and articular. This "twin-jointed jaw" can be seen in late cynodonts and early mammaliforms. *Morganucodon* is one of the first discovered and most thoroughly

studied of the mammaliforms, since an unusually large number of morganucodont fossils have been found, and

Morganucodon is an almost perfect intermediate in this respect (the "twin-jointed jaw") between the higher mammal-like reptiles on the one hand and the typical mammals on the other.

(note: "mammal-like reptiles" is an obsolete term for the therapsids)

Mammal-like jaws and ears

As the dentary continued to enlarge during the Triassic, the older quadrate-articular joint fell out of use. Some of the bones were lost, but the quadrate (which is directly connected to the stapes), the articular (connected to the quadrate) and the angular (connected to the articular) became free-floating and associated with the stapes. This occurred at least twice in the mammaliformes ("almost-mammals"). The Multituberculates, which lived from about 160M years ago (mid-Jurassic) to about 35M years ago (early Oligocene) had jaw joints that consisted of only the dentary and squamosal bones, and the quadrate and articular bones were part of the middle ear; but other features of their teeth, jaws and skulls are significantly different from those of mammals.

In the lineage most closely related to mammals, the jaws of *Hadrocodium* (about 195M years ago in the very early Jurassic) suggest that it or a very close ancestor may have been the first to have a nearly fully mammalian middle ear: it lacks the trough at the rear of the lower jaw, over which the eardrum stretched in therapsids and earlier mammaliformes, and the absence of this trough which suggests that *Hadrocodium*'s ear was part of the cranium, as it is in mammals, and hence that the former articular and quadrate had migrated to the middle ear and become the malleus and incus; but *Hadrocodium*'s dentary has a "bay" at the rear which mammals lack, a hint that that its dentary bone retained the same shape that it would have had if the articular and quadrate had remained part of the jaw joint. It has been suggested that a relatively large trough in the jaw bone of the early Cretaceous monotreme *Teinolophos* provides evidence of a pre-mammalian jaw joint, because therapsids and many mammaliforms had such troughs, in which the articular and angular bones "docked", and therefore that *Teinolophos* had a pre-mammalian middle ear; and therefore that the mammalian middle ear ossicles evolved indepedendently in monotremes and in other mammals. But a more recent analysis of *Teinolophos* concluded that the animal was a full-fledged platypus and the trough was a channel for the large number of nerves that collect signals from the electrical and vibration sensors in the bill (this is a signature feature of the platypi within monotremes), and therefore that the trough is not evidence that *Teinolophos* had a pre-mammalian jaw joint and a pre-mammalian middle ear. Ironically Rich and Vickers-Rich were among the authors of the 2005 paper on which they later cast doubt.

A recently discovered intermediate form is the primitive mammal Yanoconodon, from 125 million years ago in the Mesozoic, in which the ossicles have separated from the jaw and serve the hearing function in the middle ear, yet maintain a slender connection to the

jaw via the ossified Meckel's cartilage, which in more advanced mammals dissolves during development.

How these changes affected hearing

The frequency range and sensitivity of the ear is dependent upon the shape and arrangement of the middle-ear bones. In early synapsids such as the pelycosaurs, the quadrate and articular had to function as the jaw joint, and this severely limited how far these bones could be modified to alter the frequency range of the ear. But once these bones were no longer involved in the jaw joint, variations which affected hearing would not also affect jaw joint function, and this allowed unconstrained evolution of the mammalian hearing apparatus. By the Jurassic, the typical mammalian ear had evolved, in which the angular had become the tympanic annula (a bony support for the tympanic membrane), while the articular and quadrate had become the malleus and incus, respectively, connected in series with the stapes. This series of three bones acts as an amplification system to allow enhanced hearing.

The transition between these two states is one of the most well-documented and supported in all of evolution, and newly discovered fossils from this transitional period have recently improved our understanding of this transition. But they also suggest that it was not a simple linear process from the early therapsid jaw (quadrate-articular joint) and middle ear (with stapes as the only ossicles) to the modern mammalian condition.

Natural selection

It has been suggested that natural selection could be a factor in the preservation of the structure of the middle ear in mammals. Many of the earliest mammals were quite small, and the dentition indicates that they were insectivorous. If they were "warm-blooded" (homeothermous), like modern mammals, then they could have been nocturnal. This fits with the popular image of small, nocturnal insectivorous mammals surviving in niches not accessible to the large, dominant contemporary dinosaurs. The enhanced hearing, particularly in the higher frequencies, would be helpful for nocturnal animals, in particular for detecting insects. This scenario is consistent with selective advantage being a contributory factor to the transition.

Summary

While the stapes is present in many types of tetrapods, the addition of the incus and malleus (also known as quadrate and articular) in the middle ear is a signature feature of mammals, distinguishing them from reptiles and all other vertebrates. They therefore have the appearance of representing a discontinuity in the tree of life. But in the early 19th century, it was hypothesized that these bones are not a total novelty, but are the equivalents of two bones which non-mammals have in their jaws. This hypothesis made sense, not only of the existence of these middle-ear bones, but also of certain other features of the anatomy, such as the paths taken by nerves in the head.

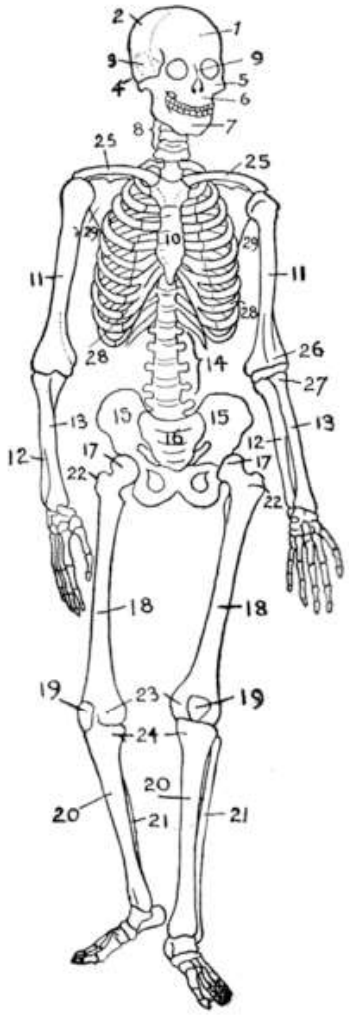
As evolutionary biology began to be expanded upon, this relationship became treated as one of common descent. For the evolutionary explanation to make sense, it seemed to demand that there would be a transition in function between being part of the feeding mechanism in the joint of the jaw and serving only in hearing; and this would mean that somehow there had to be an intermediate connecting these two quite different functions. With the discovery of *Morganucodon* and other fossils, there were concrete examples of this. There was a double jaw joint: the "older reptilian", as well as the "newer mammalian", in the same animal. This meant a confirmation of the pattern of inference from comparative anatomy to evolutionary biology.

The earliest mammals were generally small animals, probably nocturnal insectivores. This suggests a plausible evolutionary mechanism driving the change, for with these small bones in the middle ear, a mammal has extended its range of hearing for higher-pitched sounds which would improve the detection of insects in the dark. Natural selection would account for the success of this feature. And still one more connection with another part of biology: genetics suggested a mechanism for this transition, the kind of major change of function seen elsewhere in the world of life being studied by Evodevo.

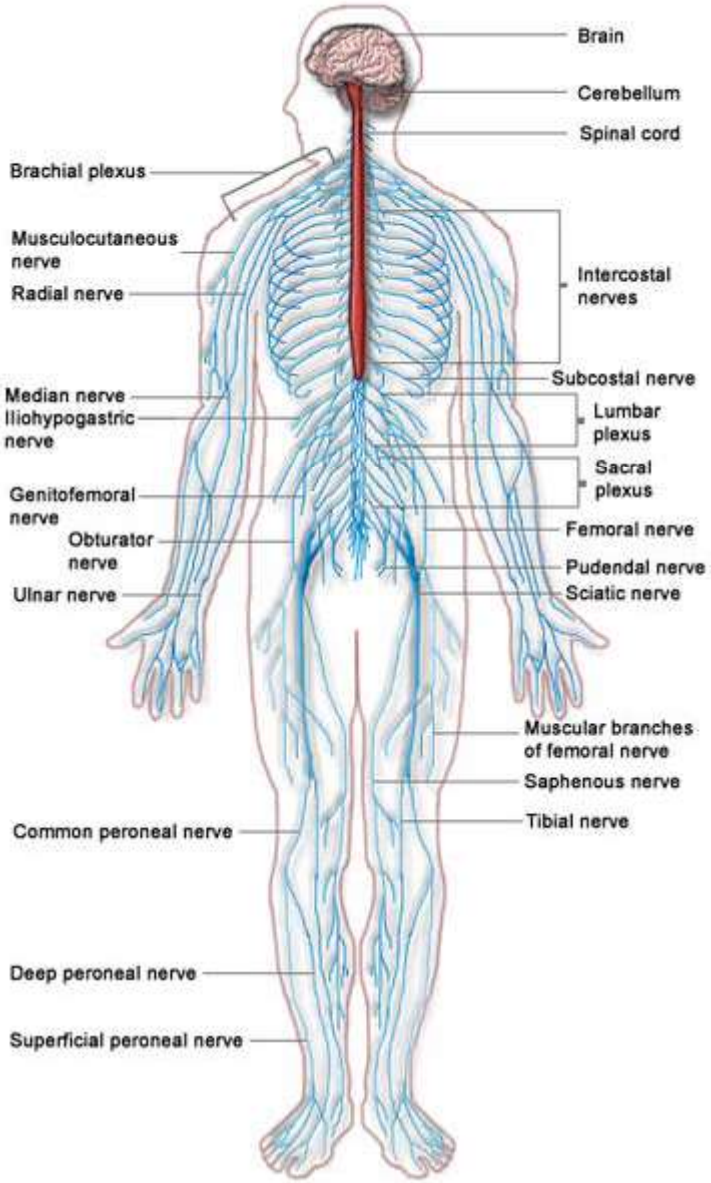
Chapter- 4

Mammal Anatomy

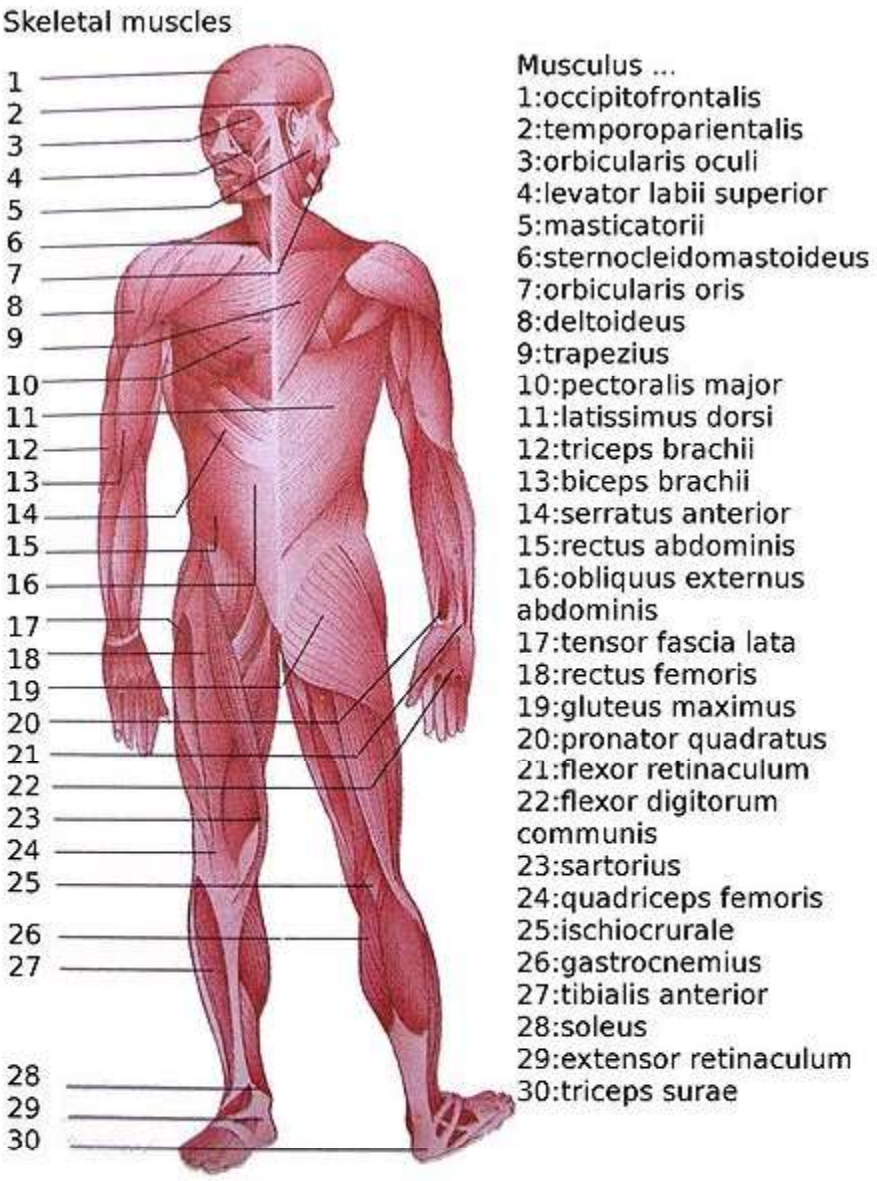
Human anatomy



The skeleton



The nervous system


Skeletal muscles
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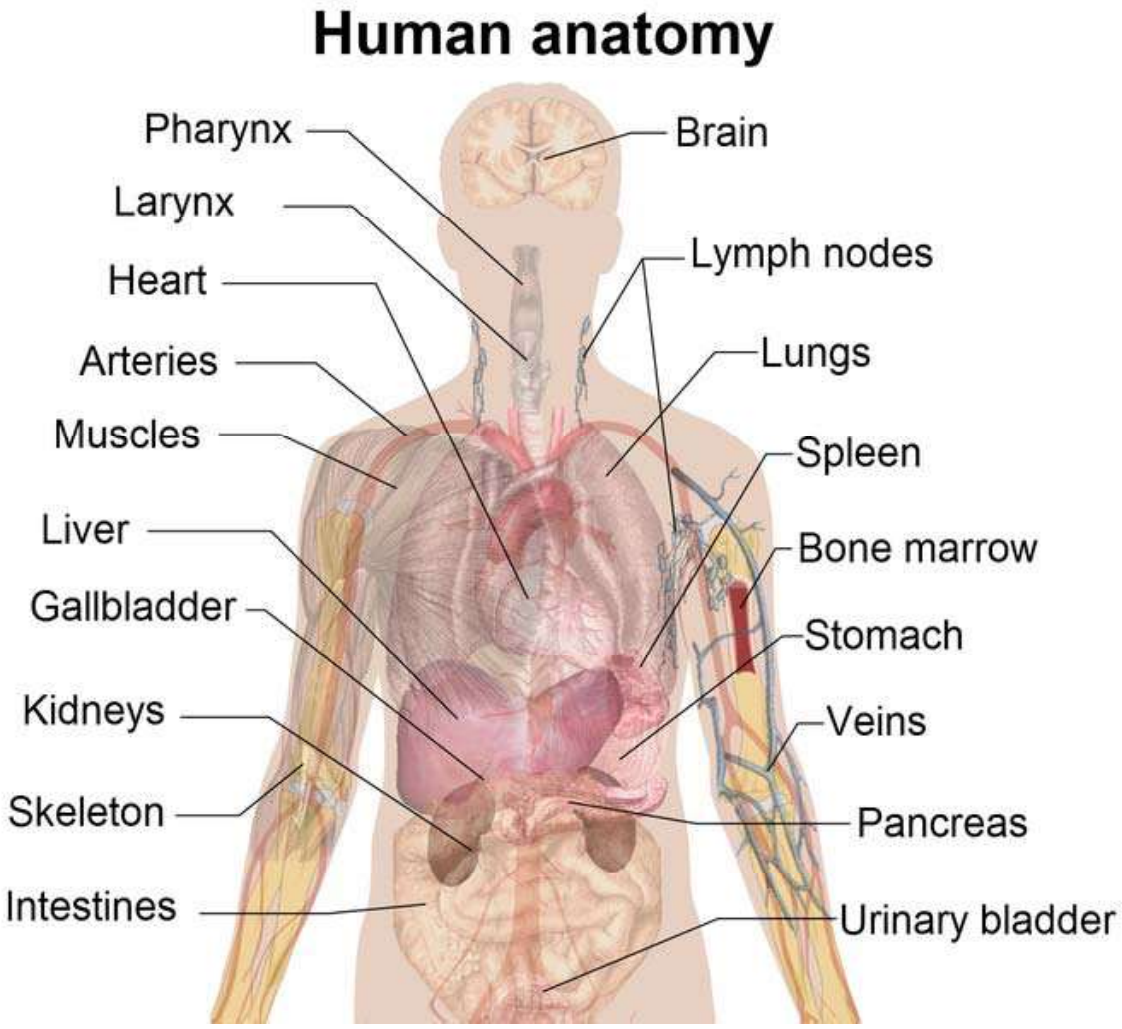
Musculus ...
1:occipitofrontalis
2:temporoparientalis
3:orbicularis oculi
4:levator labii superior
5:masticatorii
6:sternocleidomastoideus
7:orbicularis oris
8:deltoideus
9:trapezius
10:pectoralis major
11:latissimus dorsi
12:triceps brachii
13:biceps brachii
14:serratus anterior
15:rectus abdominis
16:obliquus externus abdominis
17:tensor fascia lata
18:rectus femoris
19:gluteus maximus
20:pronator quadratus
21:flexor retinaculum
22:flexor digitorum communis
23:sartorius
24:quadriceps femoris
25:ischiocrurale
26:gastrocnemius
27:tibialis anterior
28:soleus
29:extensor retinaculum
30:triceps surae

The muscles



The internal organs and their contents

Human anatomy (gr. ἀνατομία, "dissection", from ἀνά, "up", and τέμνειν, "cut"), which, with human physiology and biochemistry, is a complementary basic medical science, is primarily the scientific study of the morphology of the human body. Anatomy is subdivided into gross anatomy and microscopic anatomy. Gross anatomy (also called topographical anatomy, regional anatomy, or anthropotomy) is the study of anatomical structures that can be seen by unaided vision. Microscopic anatomy is the study of minute anatomical structures assisted with microscopes, which includes histology (the study of the organization of tissues), and cytology (the study of cells). Anatomy, physiology (the study of function) and biochemistry (the study of the chemistry of living structures) are complementary basic medical sciences when applied to the human body. As such, these subjects are usually taught together (or in tandem) to students in the medical sciences.

In some of its facets human anatomy is closely related to embryology, comparative anatomy and comparative embryology, through common roots in evolution; for example, much of the human body maintains the ancient segmental pattern that is present in all

vertebrates with basic units being repeated, which is particularly obvious in the vertebral column and in the ribcage, and can be traced from very early embryos.

The human body consists of biological systems, that consist of organs, that consist of tissues, that consist of cells and connective tissue.

The history of anatomy has been characterized, over a long period of time, by a continually developing understanding of the functions of organs and structures in the body. Methods have also advanced dramatically, advancing from examination of animals through dissection of preserved cadavers (dead human bodies) to technologically complex techniques developed in the 20th century.

Study

Generally, physicians, dentists, physiotherapists, nurses, paramedics, radiographers, and students of certain biological sciences, learn gross anatomy and microscopic anatomy from anatomical models, skeletons, textbooks, diagrams, photographs, lectures, and tutorials. The study of microscopic anatomy (or histology) can be aided by practical experience examining histological preparations (or slides) under a microscope; and in addition, medical and dental students generally also learn anatomy with practical experience of dissection and inspection of cadavers (dead human bodies). A thorough working knowledge of anatomy is required for all medical doctors, especially surgeons, and doctors working in some diagnostic specialities, such as histopathology and radiology.

Human anatomy, physiology, and biochemistry are basic medical sciences, which are generally taught to medical students in their first year at medical school. Human anatomy can be taught regionally or systemically; that is, respectively, studying anatomy by bodily regions such as the head and chest, or studying by specific systems, such as the nervous or respiratory systems. The major anatomy textbook, Gray's Anatomy, has recently been reorganized from a systems format to a regional format, in line with modern teaching.

Anatomy in arts

Gross anatomy has become a key part of visual arts. Basic concepts of how muscles and bones function and deform with movement is key to drawing, painting or animating a human figure. Many books such as "Human Anatomy for Artists: The Elements of Form", are written as a guide to drawing the human body anatomically correct. Leonardo da Vinci sought to improve his art through a better understanding of human anatomy. In the process he advanced both human anatomy and its representation in art.

Approaches

Regional groups

- Head and neck – includes everything above the thoracic inlet.
- Upper limb – includes the hand, wrist, forearm, elbow, arm, and shoulder.
- Thorax – the region of the chest from the thoracic inlet to the thoracic diaphragm.
- Human abdomen to the pelvic brim or to the pelvic inlet.
- The back – the spine and its components, the vertebrae, sacrum, coccyx, and intervertebral disks.
- Pelvis and Perineum – the pelvis consists of everything from the pelvic inlet to the pelvic diaphragm. The perineum is the region between the sex organs and the anus.
- Lower limb – everything below the inguinal ligament, including the hip, the thigh, the knee, the leg, the ankle, and the foot.

Internal organs (by region)

Head and neck

- Brain
    - Amygdala
    - Basal ganglia
    - Brain stem
        - medulla
        - midbrain
        - pons
    - Cerebellum
    - Cerebral cortex
    - Hypothalamus
    - Limbic system

- Eye
- Pituitary
- Thyroid and Parathyroids

Thorax

- Heart
- Lung
- Esophagus
- Thymus
- Pleura

Abdomen and pelvis (both sexes)

- Adrenals
- Appendix
- Bladder
- Gallbladder
- Large intestine
- Small intestine
- Kidney
- Liver
- Pancreas
- Spleen
- Stomach

Male pelvis

- Prostate
- Testes

Female pelvis

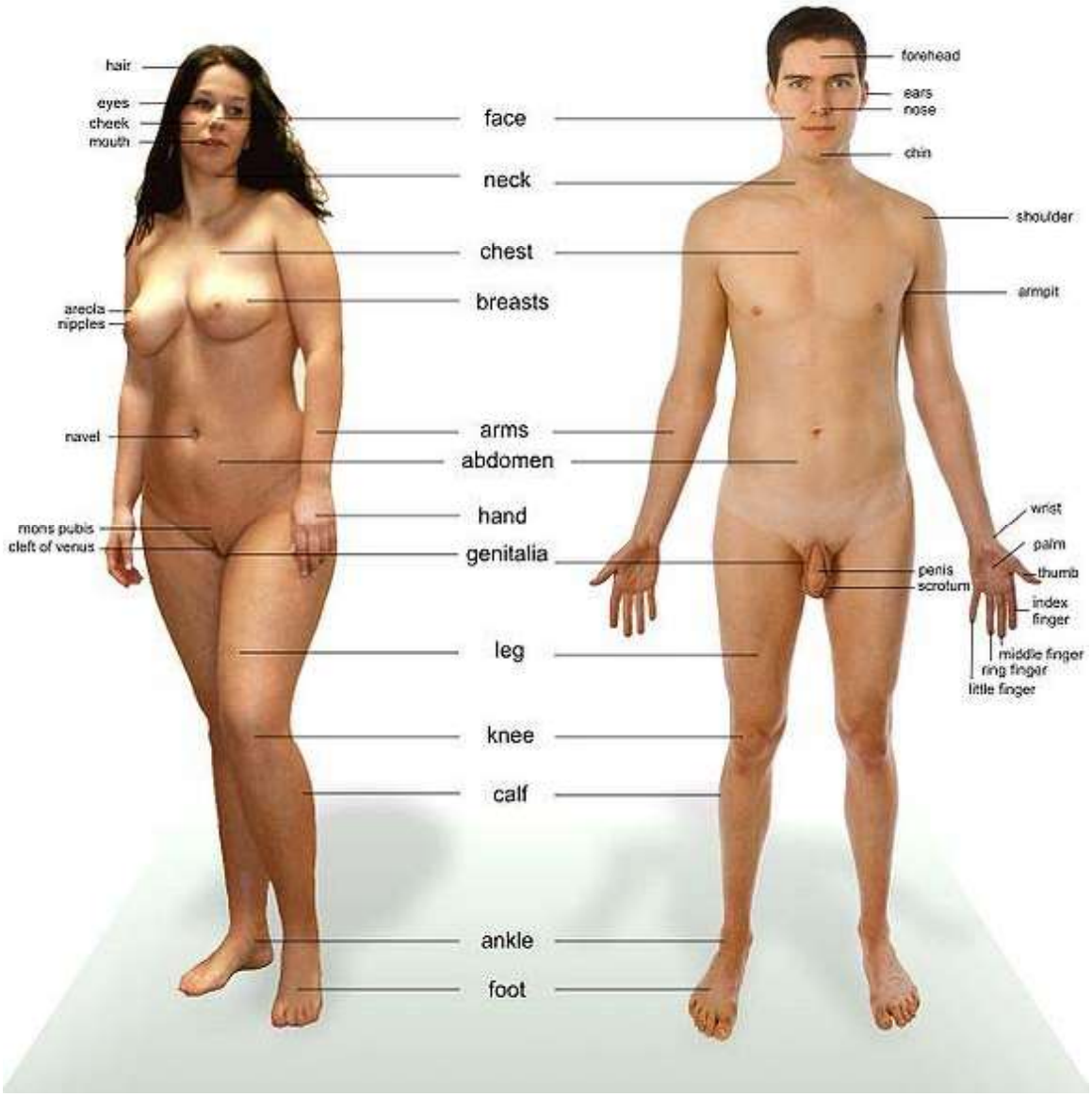
- Ovaries
- Uterus

Major organ systems

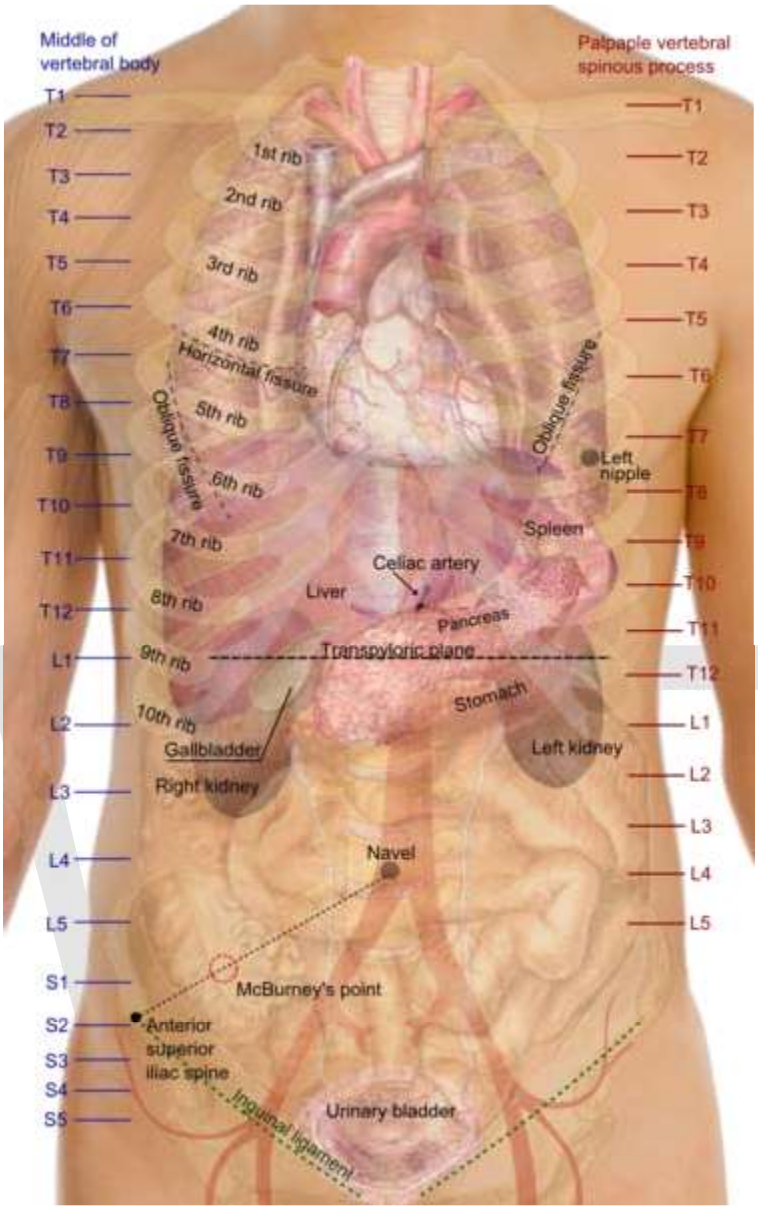
- Circulatory system: pumping and channeling blood to and from the body and lungs with heart, blood, and blood vessels.
- Digestive System: digestion and processing food with salivary glands, esophagus, stomach, liver, gallbladder, pancreas, intestines, rectum, and anus.
- Endocannabinoid system: neuromodulatory lipids and receptors involved in a variety of physiological processes including appetite, pain-sensation, mood, motor learning, synaptic plasticity, and memory.
- Endocrine system: communication within the body using hormones made by endocrine glands such as the hypothalamus, pituitary or pituitary gland, pineal body or pineal gland, thyroid, parathyroids, and adrenals or adrenal glands
- Integumentary system: skin, hair and nails
- Immune system: the system that fights off disease; composed of leukocytes, tonsils, adenoids, thymus, and spleen.
- Lymphatic system: structures involved in the transfer of lymph between tissues and the blood stream, the lymph and the nodes and vessels that transport it.
- Musculoskeletal system: muscles provide movement and a skeleton provides structural support and protection with bones, cartilage, ligaments, and tendons.
- Nervous system: collecting, transferring and processing information with brain, spinal cord, peripheral nerves, and nerves

- Reproductive system: the sex organs; in the female; ovaries, fallopian tubes, uterus, vagina, mammary glands, and in the male; testes, vas deferens, seminal vesicles, prostate, and penis.
- Respiratory system: the organs used for breathing, the pharynx, larynx, trachea, bronchi, lungs, and diaphragm.
- Urinary system: kidneys, ureters, bladder and urethra involved in fluid balance, electrolyte balance and excretion of urine.
- Vestibular system: contributes to our balance and our sense of spatial orientation.

Superficial anatomy



Superficial anatomy of female and male human body



Surface projections of the major organs of the trunk, using the vertebral column and rib cage as main reference points of superficial anatomy

Superficial anatomy or surface anatomy is important in human anatomy being the study of anatomical landmarks that can be readily identified from the contours or other reference points on the surface of the body. With knowledge of superficial anatomy, physicians gauge the position and anatomy of the associated deeper structures.

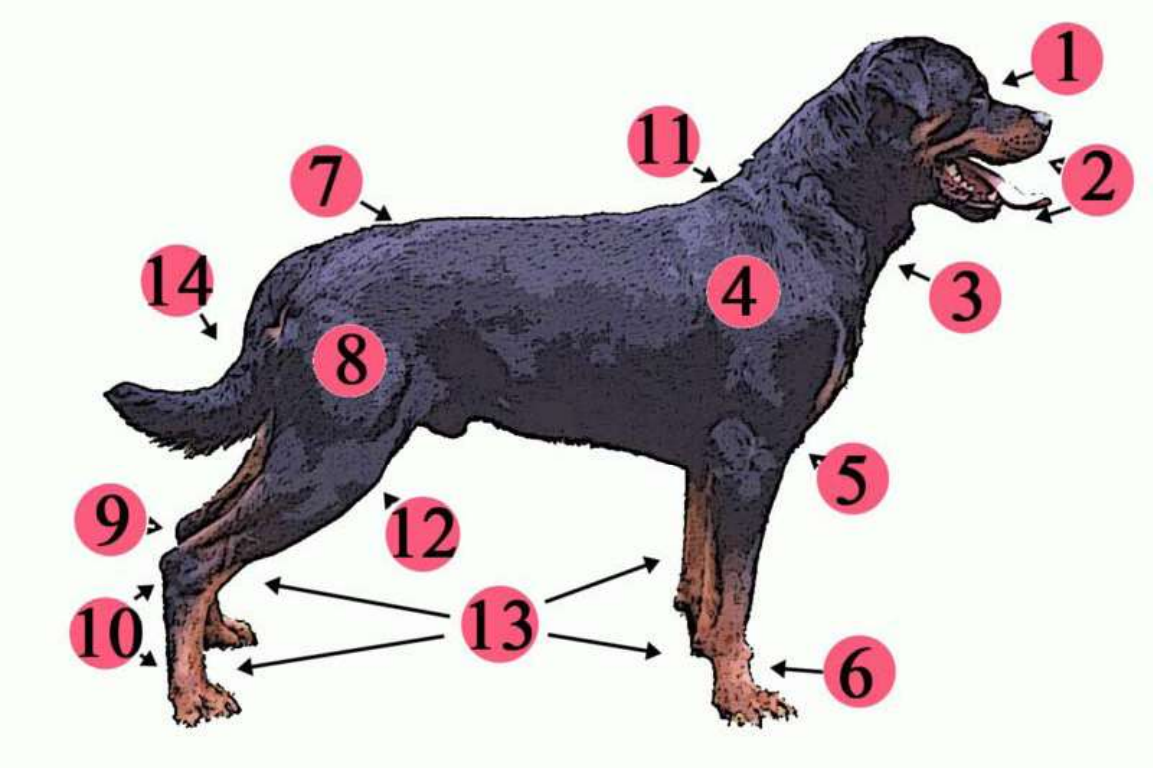
Common names of well known parts of the human body, from top to bottom:

- Head – Forehead – Jaw – Cheek – Chin
- Neck – Shoulder
- Arm – Elbow – Wrist – Hand – Finger – Thumb

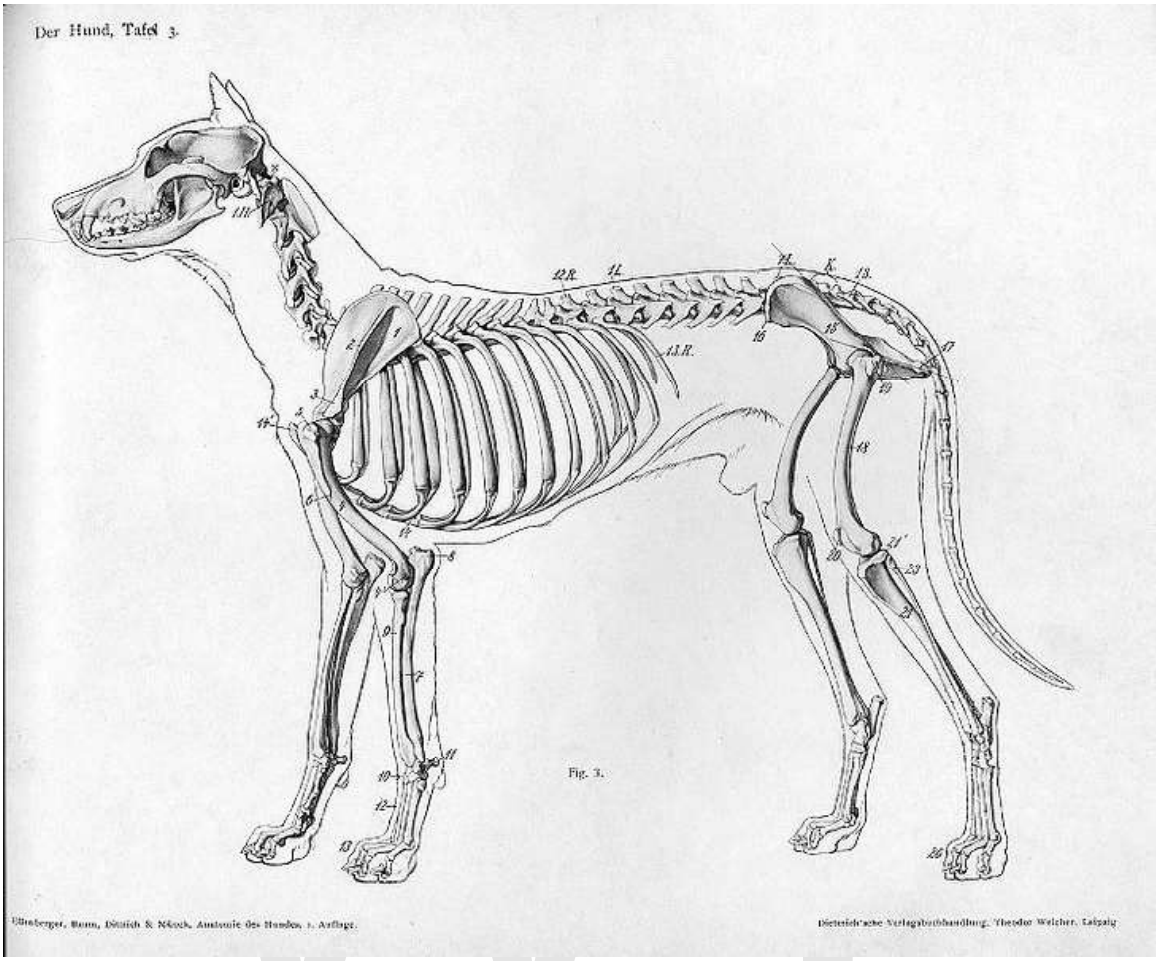
- Spine – Chest – Thorax
- Abdomen – Groin
- Hip – Buttocks – Leg – Thigh – Knee – Calf – Heel – Ankle – Foot – Toe
- Eye, ear, nose, mouth, teeth, tongue, throat, adam's apple, breast, penis, scrotum, clitoris, vulva, navel are also superficial structures.

Dog anatomy

Dog anatomy includes the same internal structures that are in humans. Details of structures vary tremendously from breed to breed, more than in any other animal species, wild or domesticated, as dogs vary from the tiny Chihuahua to the giant Irish Wolfhound.



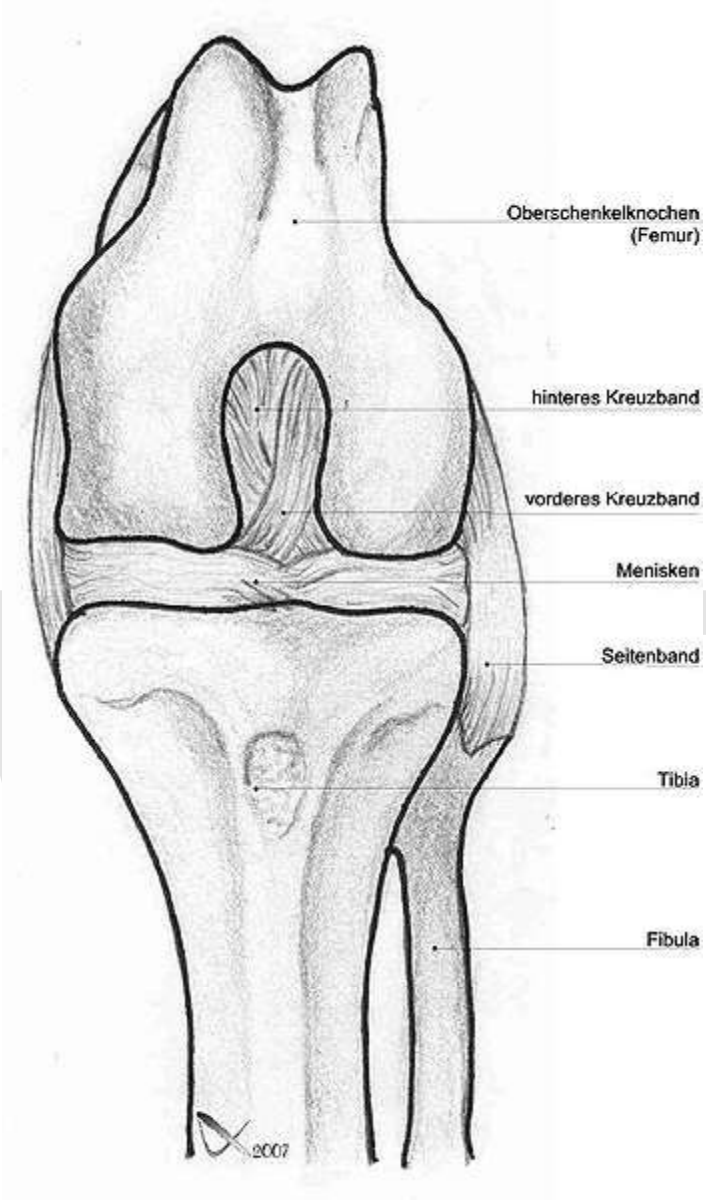
Croup 8.Leg (thigh and hip) 9.Hock 10.Hind feet 11.Withers 12.Stifle 13.Paws 14.Tail



Skeleton of a domestic dog

Skull of a dog

Physical characteristics



Dog knee

Like most predatory mammals, the dog has powerful muscles, a cardiovascular system that supports both sprinting and endurance, and teeth for catching, holding, and tearing.

The dog's ancestral skeleton provided the ability to run and leap. Their legs are designed to propel them forward rapidly, leaping as necessary, to chase and overcome prey. Consequently, they have small, tight feet, walking on their toes; their rear legs are fairly rigid and sturdy; the front legs are loose and flexible, with only muscle attaching them to the torso.

Although selective breeding has changed the appearance of many breeds, all dogs retain the basic ingredients from their distant ancestors. Dogs have disconnected shoulder bones (lacking the collar bone of the human skeleton) that allow a greater stride length for running and leaping. They walk on four toes, front and back, and have vestigial dewclaws (dog thumbs) on their front legs and sometimes on their rear legs.When a dog has extra dewclaws in addition to the usual one on each front leg, the dog is said to be "double dewclawed".

There is some debate about whether a dewclaw helps dogs to gain traction when they run because, in some dogs, the dewclaw makes contact when they are running and the nail on the dewclaw often wears down in the same way that the nails on their other toes do, from contact with the ground. However, in many dogs the dewclaws never make contact with the ground; in this case, the dewclaw's nail never wears away, and it is then often trimmed to keep it to a safe length.

The dewclaws are not dead appendages. They can be used to lightly grip bones and other items that dogs hold with the paws. However, in some dogs these claws may not appear to be connected to the leg at all except by a flap of skin; in such dogs the claws do not have a use for gripping as the claw can easily fold or turn.

There is also some debate as to whether dewclaws should be surgically removed. The argument for removal states that dewclaws are a weak digit, barely attached to the leg, so that they can rip partway off or easily catch on something and break, which can be extremely painful and prone to infection. Others say the pain of removing a dewclaw is far greater than any other risk. For this reason, removal of dewclaws is illegal in many countries. There is, perhaps, an exception for hunting dogs, who can sometimes tear the dewclaw while running in overgrown vegetation. If a dewclaw is to be removed, this should be done when the dog is a puppy, sometimes as young as 3 days old, though it can also be performed on older dogs if necessary (though the surgery may be more difficult then). The surgery is fairly straight-forward and may even be done with only local anesthetics if the digit is not well connected to the leg. Unfortunately many dogs can't resist licking at their sore paws following the surgery, so owners need to remain vigilant.

In addition, for those dogs whose dewclaws make contact with the ground when they run, it is possible that removing them could be a disadvantage for a dog's speed in running and changing of direction, particularly in performance dog sports such as dog agility.

The dog's ancestor was about the size of a Dingo, and its skeleton took about 10 months to mature. Today's toy breeds have skeletons that mature in only a few months, while giant breeds such as the Mastiffs take 16 to 18 months for the skeleton to mature. Dwarfism has affected the proportions of some breeds' skeletons, as in the Basset Hound.

Knowledge of basic anatomy also helps when competing in dog shows or contests.

Size

Researchers have identified a particular piece of genetic material that is common to every small-dog breed and, in turn, is probably responsible for making them tiny. The study, published in 2007, found a regulatory sequence (not a gene) next to the gene IGF1; together the gene and regulatory sequence together are known as a haplotype that "is a major contributor to body size in all small dogs." Medium and large size dogs do not usually have the regulatory sequence, although the small-size sequence was found in the Rottweiler breed. The study included 3,241 dogs from 143 breeds. The researchers concluded the genetic instructions to make dogs small must be at least 12,000 years old, and it is not found in wolves. Another study has shown that lap dogs (small dogs) are among the oldest dog types.

Modern dog breeds show more variation in size, appearance, and behavior than any other domestic animal. Within the range of extremes, dogs generally share attributes with their wild ancestors, the wolves. Dogs are predators and scavengers, possessing sharp teeth and strong jaws for attacking, holding, and tearing their food. Although selective breeding has changed the appearance of many breeds, all dogs retain basic traits from their distant ancestors. Like many other predatory mammals, the dog has powerful muscles, fused wristbones, a cardiovascular system that supports both sprinting and endurance, and teeth for catching and tearing.

Sight

A Greyhound, one of many breeds of sighthound

Like most mammals, dogs are dichromats and have color vision equivalent to red-green color blindness in humans. Different breeds of dogs have different eye shapes and dimensions, and they also have different retina configurations. Dogs with long noses have a "*visual streak*" which runs across the width of the retina and gives them a very wide field of excellent vision, while those with short noses have an "*area centralis*" — a central patch with up to three times the density of nerve endings as the *visual streak* — giving them detailed sight much more like a human's.

Some breeds, particularly the sighthounds, have a field of vision up to 270° (compared to 180° for humans), although broad-headed breeds with short noses have a much narrower field of vision, as low as 180°.

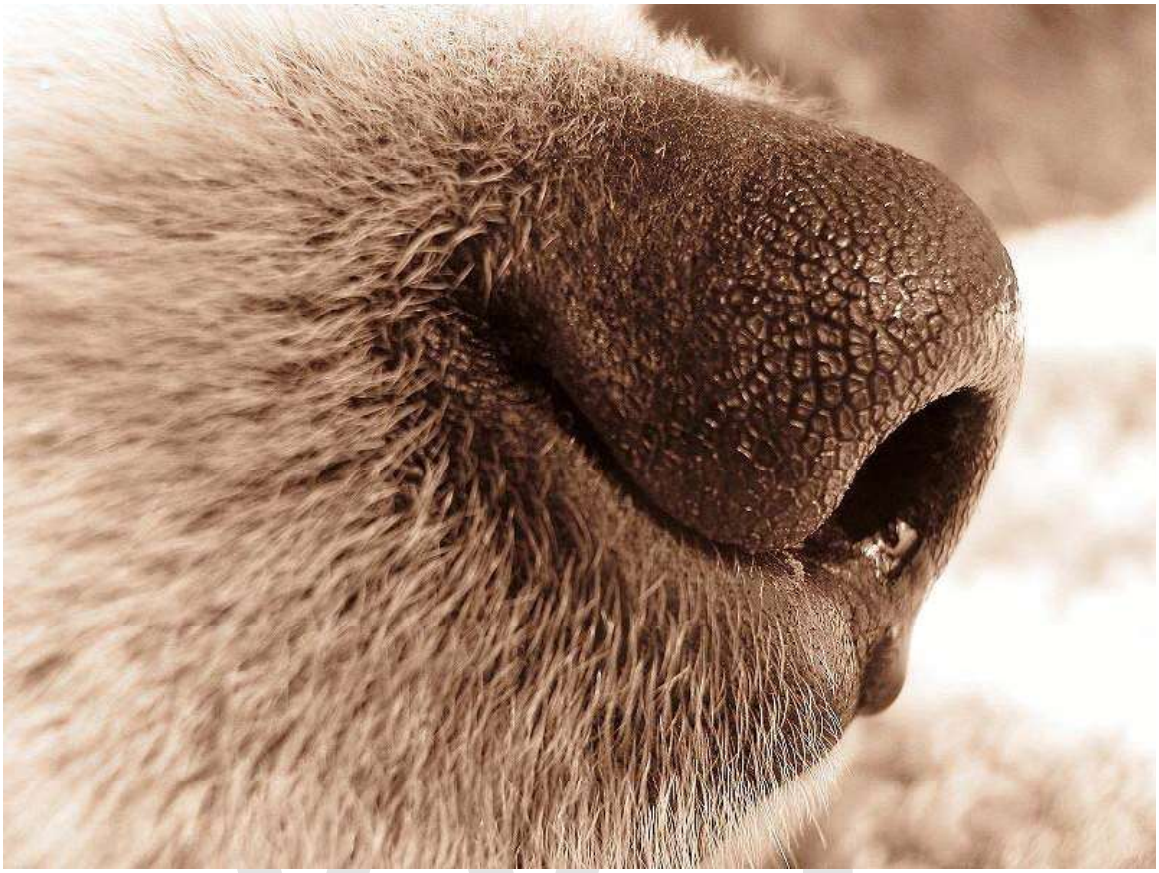
Hearing

According to hypertextbook.com, the frequency range of dog hearing is approximately 40 Hz to 60,000 Hz. Dogs detect sounds as low as the 16 to 20 Hz frequency range (compared to 20 to 70 Hz for humans) and above 45 kHz (compared to 13 to 20 kHz for humans), and in addition have a degree of ear mobility that helps them to rapidly pinpoint the exact location of a sound. Eighteen or more muscles can tilt, rotate and raise or lower a dog's ear. Additionally, a dog can identify a sound's location much faster than a human can, as well as hear sounds up to four times the distance that humans are able to. Those with more natural ear shapes, like those of wild canids like the fox, generally hear better than those with the floppier ears of many domesticated species.

Smell

Scent hounds, especially the Bloodhound, are bred for their keen sense of smell.

Dogs have nearly 220 million smell-sensitive cells over an area about the size of a pocket handkerchief (compared to 5 million over an area the size of a postage stamp for humans). According to nhm.org, dogs can sense odours at concentrations nearly 100 million times lower than humans can. According to Dummies.com, the percentage of the dog's brain that is devoted to analyzing smells is actually 40 times larger than that of a human. Some dog breeds have been selectively bred for excellence in detecting scents, even compared to their canine brethren.



The highly sensitive nose of a dog.

Coat

Domestic dogs often display the remnants of counter-shading, a common natural camouflage pattern. The general theory of countershading is that an animal that is lit from above will appear lighter on its upper half and darker on its lower half where it will usually be in its own shade. This is a pattern that predators can learn to watch for. A countershaded animal will have dark coloring on its upper surfaces and light coloring below. This reduces the general visibility of the animal. One reminder of this pattern is that many breeds will have the occasional "blaze", stripe, or "star" of white fur on their chest or undersides.

Dogs diverged from a now-extinct Asian wolf between 12,000 and 15,000 years ago, according to recent DNA studies. In that time, the long nose and heavy grey-colored double coat of the wolf has changed into the wide variety of dog shapes and coats and colors seen today. The change was due at first to genetic changes that occurred as the original dogs learned to tolerate the presence of humans, as shown in the research on foxes by Dmitri Belyaev in his Farm-Fox Experiment. The research found that a genetic change to tameness brought along other unexpected changes as well; one notable change was in the coats, changed from a typical fox coat to a spotted coat resembling a dog's

coat. As ancient dogs learned to live near humans and became less like wolves, their appearance changed as well, long before any selective breeding was done by people.

A Stanford University School of Medicine study published in Science in October, 2007 found the genetics that explain coat colors in other mammals such as in horse coats and in cat coats, did not apply to dogs. The project took samples from 38 different breeds to find the gene (a beta defensin gene) responsible for dog coat color. One version produces yellow dogs, and a mutation produces black. All dog coat colors are modifications of black or yellow. For example, the white in white miniature schnauzers is a cream color, not albinism (a genotype of e/e at MC1R.)

Modern dog breeds exhibit a diverse array of fur coats, including dogs without fur, such as the Mexican Hairless Dog. Dog coats vary in texture, color, and markings, and a specialized vocabulary has evolved to describe each characteristic.

Tail

There are many different shapes for dog tails: straight, straight up, sickle, curled, cork-screw. In some breeds, the tail is traditionally docked to avoid injuries (especially for hunting dogs). It can happen that some puppies are born with a short tail or no tail in some breeds.

Puppy characteristics

This probably 15 weeks old German shepherd mongrel already shows an upward erection trend of the ears, with varying grades of erection during the day

Puppies often have characteristics that do not last beyond early puppyhood. Eye color often changes from blue to its adult color as the puppy matures. The coat color may change: Kerry Blue Terrier puppies have black coats at birth and change to blue with maturity, and Dalmatians are white and gain their spots with age. The ear shape will also often change, especially with erect-eared breeds such as the German Shepherd Dog which have soft ears at birth, but the cartilage strengthens with age. Labrador Retrievers and other swimming dogs, start of with a very fluffy puppy coat, and over time the water

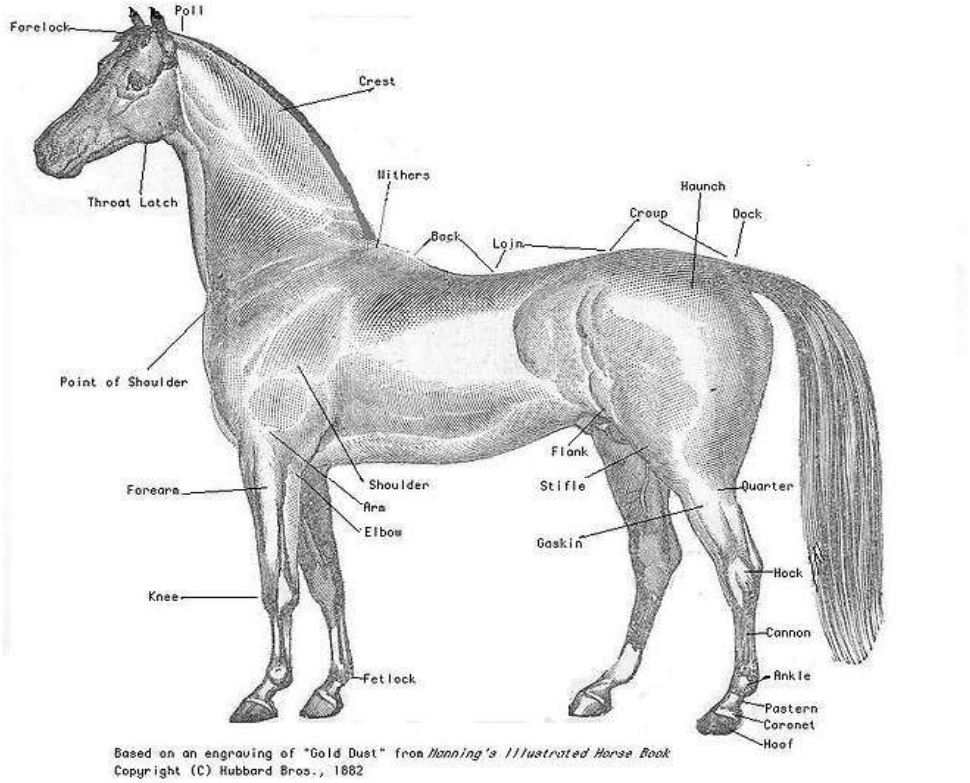
proof layer grows. Puppies that are going to grow into larger dogs, often will have over sized paws to begin with, and then the rest of them grow to fit.

Temperature regulation

It is a common misconception that dogs do not sweat. They do sweat, mainly through the footpads, but only a small fraction of a dog's excess heat is lost this way. Primarily, dogs regulate their body temperature through panting. Panting moves cooling air over the moist surfaces of the tongue and lungs, rejecting heat to the atmosphere.

Dogs possess a rete mirabile, a complex of intermingled small arteries and veins, in the carotid sinus at the base of their neck. This acts to thermally isolate the head, containing the brain, the most temperature-sensitive organ, from the body, containing the muscles, where most of the heat is generated. The result is that dogs can sustain intense physical exertion over a prolonged time in a hot environment, compared to animals which lack this apparatus; thus, a dog chasing a jackrabbit through the desert may not be able to outrun the rabbit, but it can continue the chase until the rabbit slows due to overheating.

Equine anatomy



Parts of a Horse

Equine anatomy refers to the gross and microscopic anatomy of horses and other equids, including donkeys, and zebras. While all anatomical features of equids are described in the same terms as for other animals by the International Committee on Veterinary Gross Anatomical Nomenclature in the book Nomina Anatomica Veterinaria, there are many horse-specific colloquial terms used by equestrians.

External anatomy

- **back**: the area where the saddle goes, begins at the end of the withers, extends to the last thoracic vertebrae. (Colloquially includes the loin or "coupling," though technically incorrect usage)
- **barrel**: the main body area of the horse, enclosing the rib cage and the major internal organs.
- **cannon** or **cannon bone**: The area between the knee or hock and the fetlock joint, sometimes called the "shin" of the horse, though technically it is the metacarpal III.
- **chestnut**: a callosity on the inside of each leg
- **chin groove**: the part of the horse's head behind the lower lip and chin. (the area that dips down slightly on the lower jaw). Area where the curb chain of certain bits is fastened.
- **coronet** or **coronary band**: The ring of soft tissue just above the horny hoof that blends into the skin of the leg.
- **crest**: the upper portion of the neck where the mane grows.
- **croup**: the topline of the horse's hindquarters, beginning at the hip, extending proximate to the sacral vertebrae and stopping at the dock of the tail (where the coccygeal vertebrae begin). Sometimes called "rump."
- **dock**: the point where the tail connects to the croup of the horse.
- **elbow**: The joint of the front leg at the point where the belly of the horse meets the leg. Homologous to the elbow in humans.
- **ergot**: a callosity on the back of the fetlock
- **fetlock**: Sometimes called the "ankle" of the horse, though it is not the same skeletal structure as an ankle in humans. Known to anatomists as the metacarpophalangeal (front) or metatarsophalangeal (hind) joint; homologous to the "ball" of the foot or the metacarpophalangeal joints of the fingers in humans.
- **flank**: Where the hind legs and the barrel of the horse meet, specifically the area right behind the rib cage and in front of the stifle joint.
- **forearm**: the area of the front leg between the knee and elbow. Consists of the fused radius and ulna, and all the tissue around these bones. Anatomically the antebrachium.
- **forelock**: the continuation of the mane, which hangs from between the ears down onto the forehead of the horse.
- **frog**: the highly elastic wedge-shaped mass on the underside of the hoof, which normally makes contact with the ground every stride, supports both the locomotion and circulation of the horse.
- **gaskin**: the large muscle on the hind leg, just above the hock, below the stifle. Homologous to the calf of a human.

- **girth' *or*** *heartgirth*: the area right behind the elbow of the horse, where the girth of the saddle would go, this area should be where the barrel is at its greatest diameter in a properly-conditioned horse that is not pregnant or obese.
- **hindquarters**: the large, muscular area of the hind legs, above the stifle and behind the barrel of the horse.
- **hock**: The tarsus of the horse (hindlimb equivalent to the human ankle and heel), the large joint on the hind leg.
- **hoof**: The foot of the horse. The hoof wall is the tough outside covering of the hoof that comes into contact with the ground. The hoof wall is, in many respects, a much larger and stronger version of the human fingernail.
- **jugular groove**: the line of indentation on the lower portion of the neck, can be seen from either side, just above the windpipe. Beneath this area run the jugular vein, the carotid artery and part of the sympathetic trunk.
- **knee**: the carpus of the horse (equivalent to the human wrist), the large joint in the front legs, above the cannon bone
- **loin**: the area right behind the saddle, going from the last rib of the horse to the croup. Anatomically approximate to the lumbar spine.
- **mane**: long and relatively coarse hair growing from the dorsal ridge of the neck, lying on either the left or right side of the neck).
- **muzzle**: the chin, mouth, and nostrils of the horse's face.
- **pastern**: The connection between the coronet and the fetlock. Made up of the middle and proximal phalanx.
- **poll**: commonly refers to the poll joint at the beginning of the horse's neck, immediately behind the ears, a slight depression at the joint where the atlas (C1) meets the occipital crest. Anatomically, the occipital crest itself is the "poll."
- **splints**: bones found on each of the legs, on either side of the cannon bone (8 total). Partially vestigial, these bones support the corresponding carpal bones in the forelimb, and the corresponding tarsal bones in the hindlimb. Anatomically referred to as Metacarpal/Metatarsal II (on the medial aspect (inside)) and IV (on the lateral aspect (outside)).
- **shoulder**: made up of the scapula and associated muscles. Runs from the withers to the point of shoulder (the joint at the front of the chest, i.e. the glenoid). The angle of the shoulder has a great effect on the horse's movement and jumping ability, and is an important aspect of equine conformation.
- **stifle**: Corresponds to the knee of a human, consists of the articulation between femur and tibia, as well as the articulation between patella and femur.
- **tail**: consists of both the living part of the tail (which consists of the coccygeal vertebrae, muscules, and ligaments), as well as the long hairs which grow from the living part
- **throatlatch**: The point at which the windpipe meets the head at the underside of the jaw.
- **withers**: the highest point of the thoracic vertebrae, the point just above the tops of the shoulder blades. Seen best with horse standing square and head slightly lowered. The height of the horse is measured at the withers in "hands."

Digestive system

Horses and other Equids evolved as grazing animals, adapted to eating small amounts of the same kind of food all day long. In the wild, the horse adapted to eating prairie grasses in semi-arid regions and traveling significant distances each day in order to obtain adequate nutrition. Therefore, the digestive system of a horse is about 100 feet (30 m) long, and most of this is intestines.

The mouth

Digestion begins in the mouth, which is also called the "oral cavity." It is made up of the teeth, the hard palate, the soft palate, the tongue and related muscles, the cheeks and the lips. Horses also have three pairs of salivary glands, the parotid (largest salivary gland and located near the poll), submaxillary (located in the jaw), and sublingual (located under the tongue). Horses select pieces of forage and pick up finer foods, such as grain, with their sensitive, prehensile lips. The front teeth of the horse, called incisors, clip forage, and food is then pushed back in the mouth by the tongue, and ground up for swallowing by the premolars and molars.

The esophagus

The esophagus is about 4–5 feet in length, and carries food to the stomach. A muscular ring, called the cardiac sphincter, connects the stomach to the esophagus. This sphincter is very well developed in horses. This and the oblique angle at which the esophagus connects to the stomach explains why horses cannot vomit. The esophagus is also the area of the digestive tract where horses may suffer from choke.

The stomach

Horses have a relatively small stomach for their size, and this limits the amount of feed a horse can take in at one time. The average sized horse (800 to 1200 lb) has a stomach with a capacity of only four gallons, and works best when it contains about two gallons. Because the stomach empties when 2/3 full, whether stomach enzymes have completed their processing of the food or not, and doing so prevents full digestion and proper utilization of feed, continuous foraging or several small feedings per day are preferable to one or two large ones. The horse stomach consists of a non-glandular proximal region (saccus cecus), divided by a distinct border, the margo plicata, from the glandular distal stomach.

In the stomach, assorted acids and the enzyme pepsin break down food. Pepsin allows for the further breakdown of proteins into amino acid chains. Other enzymes include resin and lipase. Additionally, the stomach absorbs some water, as well as ions and lipid soluble compounds. The end product is food broken down into chyme. It then leaves the stomach through the pyloric valve, which controls the flow of food out of stomach.

The small intestine

The horse's small intestine is 50 to 70 feet (21 m) long and holds 10 to 12 gallons. This is the major digestive organ, and where most nutrients are absorbed. It has three parts, the duodenum, jejunum and ileum. The majority of digestion occurs in the duodenum while the majority of absorption occurs in the jejunum. Bile from the liver aids in digesting fats in the duodenum combined with enzymes from the pancreas and small intestine . Horses do not have a gall bladder, so bile flows constantly. Most food is digested and absorbed into the bloodstream from the small intestine, including proteins, simple carbohydrate, fats, and vitamines A, D, and E. Any remaining liquids and roughage move into the large intestine.

The large intestine

Cecum

The cecum is the first section of the large intestine. It is also known as the "water gut" or "hind gut." It is a cul-de-sac pouch, about 4 feet (1.2 m) long that holds 7 to 8 gallons. It contains bacteria that digest cellulose plant fiber through fermentation. These bacteria feed upon digestive chyme, and also produce certain fat-soluble vitamins which are absorbed by the horse. The reason horses must have their diets changed slowly is so the bacteria in the cecum are able to modify and adapt to the different chemical structure of new feedstuffs. Too abrupt a change in diet can cause colic, as the new food is not properly digested.

Colon

The large colon, small colon, and rectum make up the remainder of the large intestine. The large colon is 10–12 feet long and holds up to 20 gallons of semi-liquid matter. It is made up of the right lower (ventral) colon, the left lower (ventral) colon, the left upper (dorsal) colon, the right upper (dorsal) colon, and the transverse colon, in that order. Three flexures are also named; the sternal flexure, between right and left ventral colon; the pelvic flexure, between left dorsal and left ventral colon; the diaphragmatic flexure, between left dorsal and right dorsal colon. The main purpose of the large colon is to absorb carbohydrates, which were broken down from cellulose in the cecum. Due to its many twists and turns, it is a common place for a type of horse colic called an impaction.

The small colon is 10–12 feet in length and holds only 5 gallons of material. It is the area where the majority of water in the horse's diet is absorbed, and is the place where fecal balls are formed. The rectum is about one foot long, and acts as a holding chamber for waste matter, which is then expelled from the body via the anus.

Reproductive system

Mare

The reproductive system of the mare is responsible for controlling gestation, birth, lactation, as well as the estrous cycle and mating behavior of the mare. It lies ventral to the 4th or 5th lumbar vertebrae, although its position within the mare can vary depending on the movement of the intestines and distention of the bladder.

The mare has two ovaries, usually 7–8 cm in length and 3–4 cm thick, that generally tend to decrease in size as the mare ages. The ovaries connect to the fallopian tubes (oviducts), which serve to move the ovum from the ovary to the uterus. To do so, the oviducts are lined with a layer of cilia, which produce a current that flows toward the uterus. Each oviduct attaches to one of the two horns of the uterus, which are approximately 20–25 cm in length. These horns attach to the body of the uterus (18–20 cm long). Caudal to the uterus is the cervix, about 5–7 cm long, which enters the vagina. Usually 3.5–4 cm in diameter, it can expand to allow the passage of the foal. The vagina of the mare is 15–20 cm long, and is quite elastic, allowing it to expand. The vulva is the external opening of the vagina, and consists of the clitoris and two labia. It lies ventral to the rectum. The mare has two mammary glands, which are smaller in virgin mares. They have two ducts each, which open externally.

Stallion

The reproductive system of the stallion is responsible for the sexual behavior and secondary sex characteristics (such as a large crest) of the stallion. The external genitalia comprise:

- the testes, which are suspended horizontally within the scrotum. The testes of an average stallion are ovoids 8 to 12 cm long;
- the penis, within the prepuce, also known as the "sheath." When not erect, the penis is housed within the prepuce, 50 cm long and 2.5 to 6 cm in diameter with the distal end 15 to 20 cm. When erect, the penis doubles in length and thickness and the glans increases by 3 to 4 times. The urethra opens within the **urethral fossa**, a small pouch at the distal end of the glans.

The internal genitalia comprise the accessory sex glands:

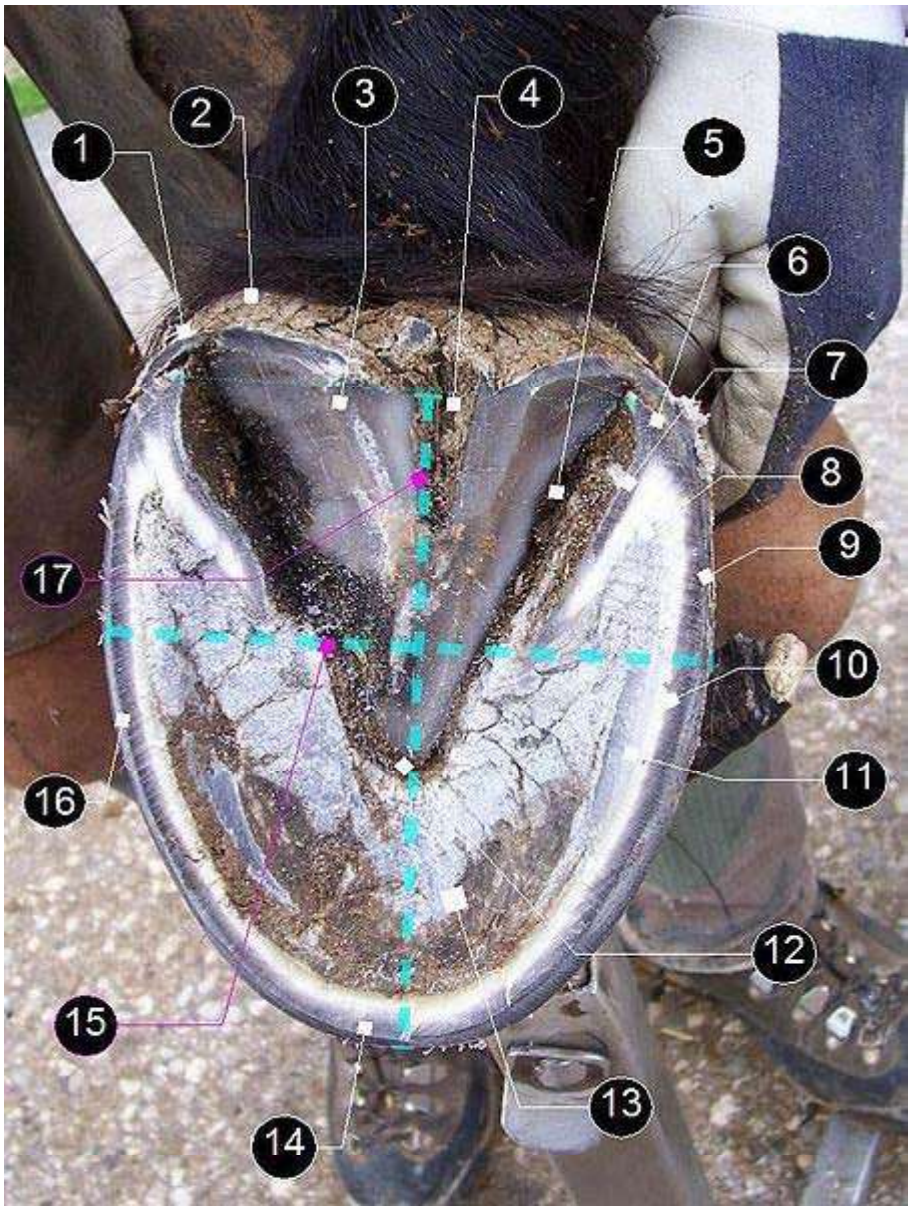
- vesicular glands;
- prostate gland; and
- bulbourethral glands.

These contribute fluid to the semen at ejaculation, but are not strictly necessary for fertility

Teeth

A horse's teeth include incisors, premolars, molars, and sometimes canine teeth. A horse's incisors, premolars, and molars, once fully developed, continue to erupt throughout its lifetime as the grinding surface is worn down through chewing. Because of this pattern of wear, a rough estimate of a horse's age can be made from an examination of the teeth.

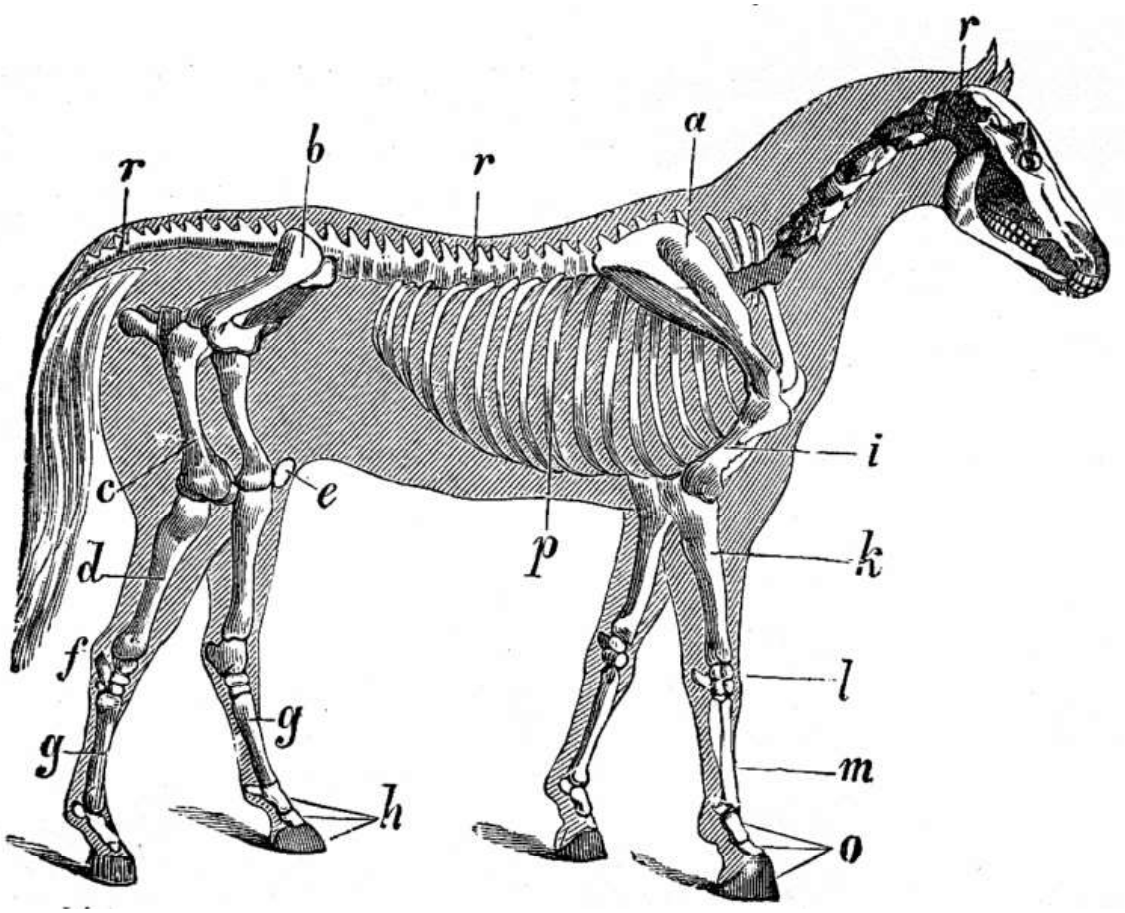
Feet/Hooves



1- Heel perioplium, 2-Bulb, 3-Frog, 4-Frog cleft, 5-Lateral groove, 6-Heel, 7-Bar, 8-Seat-of-corn, 9-Pigmented walls 10-Water line, 11-White line, 12-Apex of the frog, 13-Sole, 14-Toe, 15-How to measure hoof width (blue dotted line), 16-Quarter, 17-How to measure length (blue dotted line)

The hoof of the horse encases the second and third phalanx of the lower limbs, analogous to the fingertip or toe tip of a human. In essence, a horse travels on its "tiptoes." The hoof wall is a much larger, thicker and stronger version of the human fingernail or toenail, made up of similar materials, primarily keratin, a very strong protein molecule. The horse's hoof contains a high proportion of sulfur-containing amino acids which contribute to its resilience and toughness.

Skeletal system



A horse's skeleton

The skeleton of the horse has three major functions in the body. It protects vital organs, provides framework, and supports soft parts of the body. Horses have 205 bones, which are divided into the appendicular skeleton (the legs) and the axial skeleton (the skull, vertebral column, sternum, and ribs). Both pelvic and thoracic limbs contain the same number of bones, 20 bones per limb. Bones are connected to muscles via tendons and other bones via ligaments. Bones are also used to store minerals, and are the site of red blood cell formation.

Ligaments and tendons

Ligaments

Ligaments attach bone to bone or bone to tendon, and are vital in stabilizing joints as well as supporting structures. They are made up of fibrous material that is generally quite strong. Due to their relatively poor blood supply, ligament injuries generally take a long time to heal.

Tendons

Tendons are cords of connective tissue attaching muscle to bone, cartilage or other tendons. They are a major contributor to shock absorption, are necessary for support of the horse's body, and translate the force generated by muscles into movement. Tendons are classified as flexors (flex a joint) or extensors (extend a joint). However, some tendons will flex multiple joints while extending another (the flexor tendons of the hind limb, for example, will flex the fetlock, pastern, and coffin joint, but extend the hock joint). In this case, the tendons (and associated muscles) are named for their most distal action (digital flexion).

Tendons form in the embryo from fibroblasts which become more tightly packed as the tendon grows. As tendons develop they lay down collagen, which is the main structural protein of connective tissue. As tendons pass near bony prominences, they are protected by a fluid filled synovial structure, either a tendon sheath or a sac called a bursa.

Tendons are easily damaged if placed under too much strain, which can result in a painful, and possibly career-ending, injury. Tendinitis is most commonly seen in high performance horses that gallop or jump. When a tendon is damaged the healing process is slow because tendons have a poor blood supply, reducing the availability of nutrients and oxygen to the tendon. Once a tendon is damaged the tendon will always be weaker, because the collagen fibres tend to line up in random arrangements instead of the stronger linear pattern. Scar tissue within the tendon decreases the overall elasticity in the damaged section of the tendon as well, causing an increase in strain on adjacent uninjured tissue.

Muscular system

When a muscle contracts, it pulls a tendon, which acts on the horse's bones to move them. Muscles are commonly arranged in pairs so that they oppose each other (they are "antagonists"), with one flexing the joint (a flexor muscle) and the other extending it (extensor muscle). Therefore, one muscle of the pair must be relaxed in order for the other muscle in the pair to contract and bend the joint properly. A muscle is made up of several muscle bundles, which in turn are made up of muscle fibers. Muscle fibers have myofibrils, which are able to contract due to actin and myosin. A muscle together with its tendon and bony attachments form an extensor or flexor unit.

Respiratory system and smell

The horse's respiratory system consists of the nostrils, pharynx, larynx, trachea, diaphragm, and lungs. Additionally, the nasolacrimal duct and sinuses are connected to the nasal passage. The horse's respiratory system not only allows the animal to breathe, but also is important in the horse's sense of smell (olfactory ability) as well as in communicating.

Circulatory system

The horse's circulatory system includes the four-chambered heart, averaging 8.5 lb (3.9 kg) in weight, as well as the blood and blood vessels. Its main purpose is to circulate blood throughout the body to deliver oxygen and nutrients to tissues, and to remove waste from these tissues. The frog (the V shaped part on the bottom of the horses hoof)is a very important part of the circulatory system. The frog consists of blood vessel filled tissue. When the horse steps, the ground pushes upward compressing the frog and causing the digital cushion to sqeeze the blood upward and back up the leg towards the heart. Helping the heart work against gravity.

The eye

A horse's eye

The horse has the largest eye of all land mammals, and is designed to help the horse as a prey animal. It provides the horse with a wide field of monocular vision, as well as good visual acuity and some ability to see color. Because the horse's vision is closely tied to his behavior, the horse's visual abilities are often taken into account when handling and training the animal.

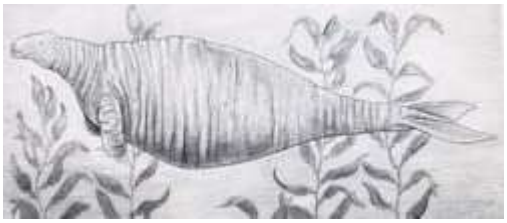
Hearing

The pinna of a horse's ears can rotate in any direction to pick up sounds

The hearing of horses is good, superior to that of humans, and the pinna of each ear can rotate up to 180°, giving the potential for 360° hearing without having to move the head. Often, the eye of the horse is looking in the same direction as the ear is directed

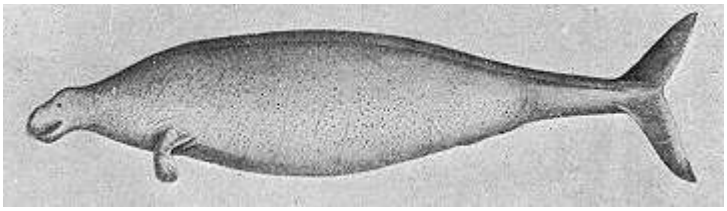
Chapter- 5

Steller's Sea Cow



Steller's sea cow (*Hydrodamalis gigas*) was a large herbivorous marine mammal. In historical times, it was the largest member of the order Sirenia, which includes its closest living relative, the dugong (*Dugong dugon*), and the manatees (*Trichechus spp.*). Formerly abundant throughout the North Pacific, its range was limited to a single, isolated population on the uninhabited Commander Islands by 1741 when it was first described by Georg Wilhelm Steller, chief naturalist on an expedition led by explorer Vitus Bering. Within 27 years of discovery by Europeans, the slow moving and easily captured Steller's sea cow was hunted to extinction.

Description



Drawing of Steller's sea cow, by Georg Steller. Note that the broad, flattened tail is drawn at an angle in order to show its shape.

The sea cow grew at least 8 metres (26 ft) to 9 meters or 30 feet long, much larger than the manatee or dugong. Steller's work contains two contradictory weights: 4 and 24.3 tons. The true value probably lies between these figures, around 8-10 tons. It looked somewhat like a large seal, but had two stout forelimbs and a whale-like tail. According to Steller, "The animal never comes out on shore, but always lives in the water. Its skin is black and thick, like the bark of an old oak…, its head in proportion to the body is small…, it has no teeth, but only two flat white bones—one above, the other below". It was completely tame, according to Steller. They fed on a variety of kelp. Wherever sea

cows had been feeding, heaps of stalks and roots of kelp were washed ashore. The sea cow was also a slow swimmer and apparently was unable to submerge.

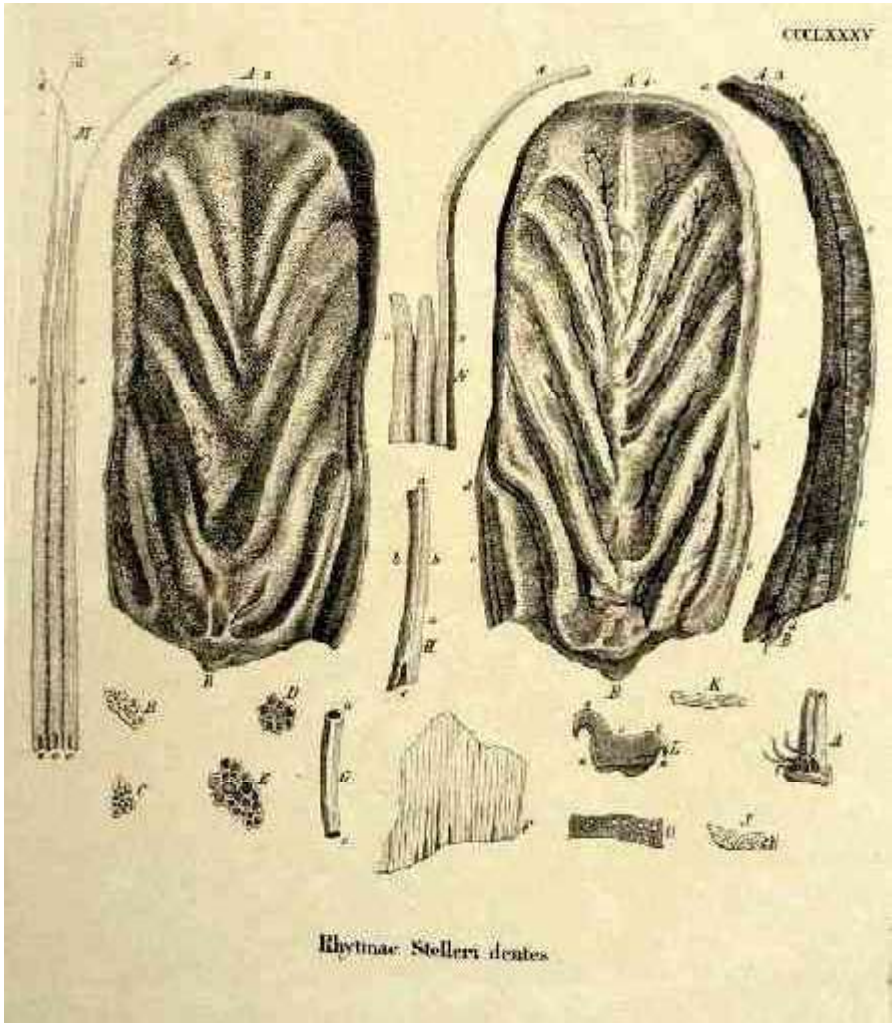
Population and extinction

Hydrodamalis gigas skeleton with incorrectly restored hands, Muséum national d'histoire naturelle, Paris

skull

The population of sea cows was small and limited in range when Steller first described them. Steller said they were numerous and found in herds, but zoologist Leonhard Hess Stejneger later estimated that at discovery there had been fewer than 1,500 remaining, and thus had been in immediate danger of extinction from overhunting by humans. They were quickly wiped out by the sailors, seal hunters, and fur traders that followed Bering's

route past the islands to Alaska, who hunted them both for food and for their skins, which were used to make boats. They were also hunted for their valuable subcutaneous fat, which was not only used for food (usually as a butter substitute), but also for oil lamps because it did not give off any smoke or odor and could be kept for a long time in warm weather without spoiling. By 1768, 27 years after it had been discovered by Europeans, Steller's sea cow was extinct.



Grinding plates.

Fossils indicate that Steller's sea cow was formerly widespread along the North Pacific coast, reaching south to Japan and California. Given the rapidity with which its last population was eliminated, it is likely that aboriginal hunting caused its extinction over the rest of its original range (aboriginal peoples apparently never inhabited the Commander Islands).

It has been argued that the sea cow's decline may have also been an indirect response to the harvest of sea otters by aboriginal people from the inland areas. With the otters

reduced, the population of sea urchins would have increased and reduced availability of kelp, the Steller's Sea Cow's primary source of food. Thus, aboriginal hunting of both species may have contributed to the sea cow's disappearance from continental shorelines. However, in historic times aboriginal hunting had depleted sea otter populations only in localized areas. The sea cow would have been easy prey for aboriginal hunters, who would likely have exterminated accessible populations with or without simultaneous otter hunting. In any event, the sea cow was limited to coastal areas off islands without a human population by the time Bering arrived, and was already endangered.

In literature

Group of Steller's sea cows in a painting from 1902.

Sea cows appear in Rudyard Kipling's short story "The White Seal", where they show the title character a place of refuge from human hunters. Kipling probably knew (a) that the sea cow was considered extinct and (b) that nevertheless people sometimes claimed to have seen them. Thus, his suggestion is that they are around, but mostly hiding.

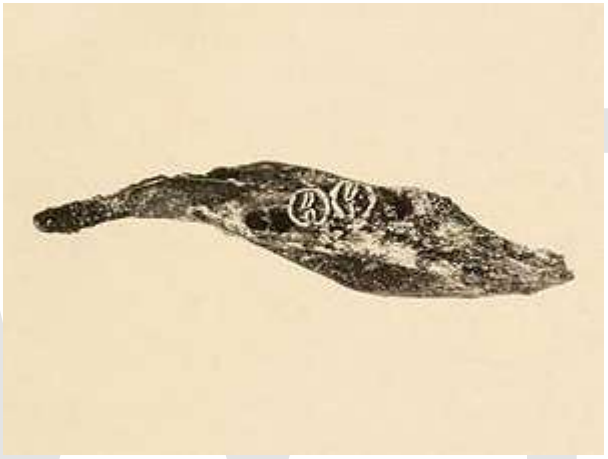
In Jules Verne's 1870 novel *20000 Leagues Under the Sea*, the travelers in Captain Nemo's fictional submarine *Nautilus* encounter various sirenians during their journey. On February 10 they encounter a female dugong in the Red Sea; Nemo states that hunting has made sirenians scarce, yet Ned Land harpoons the animal to eat. It is described as over 7 m long with a mass of 5000 kg (a size far excessive for a dugong in that habitat, though appropriate for Steller's sea cow, found in colder northern waters but already by then extinct for a century). On April 12, observing a group of West Indian Manatees off Dutch Guiana, Professor Arronax extols their ecological value. Thus, environmental themes were expressed in Verne's writing; though some details may be inexact, this book has likely contributed to a wider public awareness of marine biology and interest in conservation.

In the contemporary literature, Steller's sea cow appears in a book of poetry *Species Evanescens* by Russian poet Andrei Bronnikov. In this book the poet compares the fate of the exterminated animal with the fate of its discoverer. The book examines the personality of Georg Steller and depicts the Kamchatka expedition during which the discovery of the Steller's sea cow had been made.

Chapter- 6

Extinct Rodents

Oriente Cave Rat



Oriente Cave Rat

The **Oriente Cave Rat** (***Boromys offella***) was a species of rodent in the Echimyidae family. It was endemic to Cuba. Its natural habitat was subtropical or tropical moist lowland forests. It is known from recent fossil records, and may have become extinct with the introduction of other rats.

White-footed Rabbit-rat

White-footed rabbit-rat

The **White-footed Rabbit-rat** (***Conilurus albipes***) is an extinct species of rodent, which was originally found in woodlands from Adelaide to Sydney, but became restricted to south-eastern Australia. It was kitten-sized and was one of Australia's largest native rodents. It was nocturnal and lived among trees. It made nests filled with leaves and possibly grass in the limbs of hollow eucalyptus trees. The mother carried her young attached to her teats. John Gould said that he removed a baby from a teat of its dead mother. The baby clung tightly to Gould's glove.

Sydney natives called it 'gnar-ruck' which translates as 'rabbit-biscuit'. It was a problem in the settlers' stores at about 1788. The last specimen was recorded at about 1845, but some were reported in 1856-57 and perhaps in the 1930s. Rats may have transmitted disease or competed directly with the white-footed rabbit rat. Cats may have been predators, while the demise of Aboriginal firestick farming, which maintained woodland, may have doomed the rabbit rat and its habitat.

Oryzomys nelsoni

Oryzomys nelsoni is an extinct rodent of María Madre Island, Nayarit, Mexico. Within the genus *Oryzomys* of the family Cricetidae, it may have been most closely related to the mainland species *O. albiventer*. Since its first description in 1898, most authors have regarded it as a distinct species, but it has also been classified as a mere subspecies of the marsh rice rat (*O. palustris*).

After its discovery in 1897, it has never been recorded again and it is now considered extinct; the presence of introduced black rats on María Madre may have contributed to its extinction. *Oryzomys nelsoni* was a large species, distinguished in particular by its long tail, robust skull, and large incisors. It was reddish to yellowish above and mostly white below. Its diet may have included plant material and small animals.

Taxonomy

Oryzomys nelsoni was collected by Edward William Nelson and Edward Goldman in May 1897 and never found again. Their visit for the Biological Survey of the United States Department of Agriculture was one of the first scientific explorations of the islands. Clinton Hart Merriam identified the mammals they obtained, including four specimens of *Oryzomys nelsoni*, which were deposited in the United States National Museum and remain there. He named it as a species of the genus *Oryzomys*, *Oryzomys nelsoni*; the specific name honors Nelson. Investigators have generally retained it as a species distinct from other *Oryzomys*, but in 1971 Hershkovitz listed it as one of many subspecies of *Oryzomys palustris*, which he envisaged as a wide-ranging species encompassing what is now the marsh rice rat (*O. palustris*) of the southern and eastern United States, *O. couesi* of Central America, and several other species with more limited distributions.

In his 1918 revision of North American *Oryzomys*, Goldman considered *O. nelsoni* to be most closely related to the nearest mainland subspecies of *O. couesi*, *O. couesi mexicanus*. In 2009, Michael Carleton and Joaquin Arroyo-Cabrales revised the *Oryzomys* of western Mexico and confirmed that *O. nelsoni* is a very distinct species. Their morphometrical analysis found some resemblance between the species and *Oryzomys albiventer* of interior mainland Mexico, and they suggested that although

O. nelsoni likely represents an old, distinctive lineage, it may have derived from a common ancestor with *O. albiventer*.

Oryzomys nelsoni is one of about eight species in the genus *Oryzomys*, which occurs from the eastern United States (*O. palustris*) into northwestern South America (*O. gorgasi*). *O. nelsoni* is further part of the *O. couesi* section, which is centered around the widespread Central American *O. couesi* and also includes various other species with more limited and peripheral distributions. Many aspects of the systematics of the *O. couesi* section remain unclear and it is likely that the current classification underestimates the true diversity of the group. *Oryzomys* previously included many other species, which were progressively removed in various studies culminating in a contribution by Marcelo Weksler and coworkers in 2006 that removed more than forty species from the genus. All are classified in the tribe Oryzomyini ("rice rats"), a diverse assemblage of American rodents of over a hundred species, and on higher taxonomic levels in the subfamily Sigmodontinae of family Cricetidae, along with hundreds of other species of mainly small rodents.

Common names proposed for this species include Nelson Rice Rat, Nelson's Rice Rat, Nelson's Oryzomys, and Tres Marias Island Rice Rat.

Description

Skull of *Oryzomys nelsoni*, seen from below.

Oryzomys nelsoni was a large and long-tailed *Oryzomys*; its tail was longer than that of any other western Mexican *Oryzomys*. The upperparts were ochraceous to buff, most richly so on the rump, and paler further to the front and low on the flanks. On the head and the back, blackish hairs somewhat darkened the overall color. The underparts were white, with lead-colored underfur that was visible in some places. The ears were covered on both sides with scanty grayish hairs. The large hindfeet were sparsely covered with pale hairs. The tail was largely dark, but the underside of the basal one third to one half was light yellow.

Oryzomys nelsoni was distinctive in its large skull with broad, well-developed incisors and a strong front part (rostrum) that is strongly curved downwards. In *O. albiventer*, the rostrum and incisors were not as massive, but the molars are larger. The interparietal

bone, part of the roof of the braincase, was broad and the incisive foramina, which perforated the palate between the incisors and the molars, were relatively short.

Total length in the four known specimens is 282 to 344 mm (11.1 to 13.5 in), averaging 322 mm (12.7 in); head and body length is 122 to 153 mm (4.8 to 6.0 in), averaging 140.5 mm (5.53 in); tail length is 160 to 191 mm (6.3 to 7.5 in), averaging 181.5 mm (7.15 in); and hindfoot length is 35 to 39 mm (1.4 to 1.5 in), averaging 37.3 mm (1.47 in).

Ecology and extinction

Nelson and Goldman found the species only in a damp, herbaceous site now known as the "Sacatal" near a spring high on María Madre Island, the largest of the Islas Marías off the coast of Nayarit, western Mexico, and Nelson wrote that it was rare. He gave the elevation of this place as 1800 ft, which Álvarez-Castañeda and Méndez converted to 550 m, but in his 1918 paper, Goldman gave 800 ft instead, which Carleton and Arroyo-Cabrales in 2009 converted to 245 m. The next survey of small mammals on the island took place in March 1976 by a team led by Don E. Wilson. They failed to collect *O. nelsoni* and instead found only the introduced black rat (*Rattus rattus*) at the locality where Nelson and Goldman had collected *O. nelsoni*; this species may have contributed to the decline of the indigenous rodent.

The species is now considered extinct, although as late as 2002 the Mexican government listed it as "threatened". Another Islas Marías endemic, the deermouse *Peromyscus madrensis*, still occurred on María Madre in 1976. *Oryzomys nelsoni* is thought to have fed on plant material such as weeds, fruit, and seeds, and more rarely on animals such as fish and invertebrates.

Megalomys desmarestii

Megalomys desmarestii

Megalomys desmarestii, also known as the **Martinique Muskrat**, **Desmarest's Pilorie**, or the **Antillean Giant Rice Rat**, is an extinct rice rat from Martinique in the Caribbean. It was among the largest species of West Indian rice rat, as big as a cat, and was one of

the first Caribbean mammals to become extinct during the 20th century. It may have been aquatic, as it was known to escape into the sea when pursued by predators, but it never swam away from the island. It was common on Martinique until the end of the nineteenth century, when attempts were made to exterminate it because it was considered to be a pest in the island's coconut plantations. It was also hunted for food; but to subdue its musky odor before as a cuisine, people had to singe off its hair, expose its body overnight and boil it in two batches of water. On 8 May 1902, the volcano Mount Pelée erupted, completely destroying the island's principal city of Saint-Pierre. It has been speculated that the rice rat became extinct then or during a later eruption in 1902, but predation by introduced mongooses is more likely to have been the primary cause of its extinction.

Gould's Mouse

Gould's Mouse

Gould's Mouse (***Pseudomys gouldii***) lived in eastern inland Australia, and was named after John Gould's wife, Elizabeth. It was slightly smaller than a black rat, and quite social, living in small family groups that sheltered by day in a nest of soft, dry grass in a burrow. It usually dug burrows at a depth of 15 cm under bushes. Gould's mouse was common and widespread before European settlement, but disappeared rapidly after the 1840s, perhaps being exterminated by cats. Alternatively, it may have been out-competed by the introduced rats and mice, succumbed to introduced diseases or been affected by grazing stock and changed fire regimes. The last specimens were collected in 1856-57, and it is presumed to be extinct.

There is some speculation that this species was in fact an eastern of population of the Shark Bay Mouse. Once the Alice Springs Mouse was thought to be extinct but with genetic testing in 1998 scientists confirmed that the Alice Springs Mouse was also the Shark Bay Mouse, and this could also one day happen between Gould's Mouse and the Shark Bay Mouse.

Pemberton's Deer Mouse

From the Greek "pero" = "boots", "mys" meaning "mouse"

The "Mouse With Boots", referring to the white feet.

This group of species Peromyscus, also known as the deer mouse, are the most common North American mammals. They tend to occur in range from Alaska to Central America in many different habitats. For the fact that they are so abundant in nature, these mice constitute a large component of the nearctic ecosystems. These mice have also been of very great importance to the scientific esearch, both the wild type and the genetically variant have been used for laboratory researches. They do differ from the house mouse and the rats, because they are not closely related to these species.

General information

Peromyscus are very cold-tolerant species, they do prefer to live and survive in temperatures between 22–25°C. They are usually sexually mature by 55 days of age. Gestation is 23 days, except in lactating females where it is delayed by 4–6 days to 28 or 30 days. Peromyscus breed in mated pairs.

Most species have potential life spans of 4–5 years. Mice of the genus Peromyscus range in adult size from 15 g to 150 g. They mostly feed on seeds and berries which constitute about 75% of the diet and about 25% is other animal material. A few are more insectivorous.

Pemberton's Deer Mouse (*Peromyscus pembertoni*) lived on San Pedro Nolasco Island (located: 27°58′03″N 111°22′42″W / 27.96749°N 111.37845°W) in the Gulf of California. The last 12 specimens were collected on 26 December 1931.

This species is no doubt very poorly known. The only island that supported two different species of Peromyscus- namely 1)Peromyscus (P. pembertoni) 2)Peromyscus (P. boylii)- was San Pedro Nolasco. And they are only known because of the fact that they were collected on this island. Besides these two species no other mammals occurred on the island. They were found or collected on a steep hill covered with grass on the eastern side of the island. The dominant plants found there are as follows: Tree torote, pitayita, liga, Adam's tree, leather plant, fishhook cactus, malva rosa, chain fruit cholla, cardon, slipper plant, jojoba, and organpipe cactus.

Physical description

Peromyscus pembertoni is a medium-sized Peromyscus. No significant sexual dimorphism is evident. The tail is usually longer than the head and body is bicolored. Well haired, and tufted at the end. The hind foot is small and similar in length to the ear but sometimes longer. Skull is medium-sized and auditory bullae are not greatly inflated. Upperparts of pelage are medium brown; sides lighter brown with a broad orange lateral line extending from cheek to hindquarters; underparts whitish; ankles dusky gray; and feet whitish below ankle.

Reproduction

The social behaviour of P. pembertoni has not been very well studied or investigated. Very little information is available on the mating system. Breeding in P. pembertoni occurs throughout most of the year, although the majority of young are born in spring and early summer. Breeding may cease during winter months.

Communication and perception

Like other Peromyscus species, they have keen eyesight and vision and extensively use chemical cues in communication.

Predation

P. pembertoni escapes predation through their nocturnal and secretive habits. They are important prey items for many predatory mammals such as preys of birds, snakes, foxes, owls, and hawks.

Life span

The longevity of Peromyscus is typically short with few living more than one year or less under natural conditions.

Lesser Stick-nest Rat

Lesser Stick-nest Rat

The **Lesser Stick-nest Rat** or **White-tipped Stick-nest Rat** (***Leporillus apicalis***) lived in Southern inland Australia. It accumulated large mounds of sticks to construct its nests, which were up to three metres long and a metre high. It was easily tamed, sometimes climbing onto tables to get sugar. It was also eaten by people. The last capture was filmed on 18 July 1933, when the stick-nests were set alight. The specimens are held in the South Australian Museum. The rat may have declined from competition with cattle and sheep. There is a possibility that a Lesser Stick-nest Rat was seen in a cave in Western Australia in 1970.

2008 IUCN Change of Status

The 2008 release of the updated IUCN Status for the **Lesser Stick-nest Rat**, has interestingly 'downgraded' their status from Extinct to Critically Endangered (Possibly Extinct), owing to the very slight possibility that a very small population may still exist in yet to be surveyed remote lands of the Australian interior.

On the site, the reasoning is "Listed as Critically Endangered (Possibly Extinct) because, although there are no confirmed reports of this species since 1933, there is a reliable record from 1970 and continued, occasional reports of fresh vegetation being added to

old stick-nests. Much of this species' range is in remote portions of central Australia, which have not been fully surveyed. This species is probably extinct, but if it does persist its numbers would almost certainly be very small."

Chadwick Beach Cotton Mouse

The **Chadwick Beach Cotton Mouse** (*Peromyscus gossypinus restrictus)* is a presumed extinct subspecies of the Cotton Mouse (*Peromyscus gossypinus*) from the genus Peromyscus. It was confined to a small area on the Manasota Key peninsula in Florida.

Description

The Chadwick Beach Cotton Mouse was smaller and paler than the nominate race. The total length was 172 mm, the tail length 72.5 mm, the hind foot length 22.3 mm, the ear length 22.3 mm and largest skull length was 27.6 mm. The zygomatic breadth was 13.9 mm, the preorbital breadth was 4.4 mm, the nasal length was 10.9 mm and the length of the teeth in the maxilla was 3.9 mm. The upperparts were pink cinnamon with a rufous hue in the middle of the back. The underparts were white with a pale pink buff wash on the chest. The tail was brown above and buff below. The dorsal stripe in the middle of the back was smaller than in the nominate race.

Distribution

The mouse was primarily found in the Chadwick Beach area at Englewood in Sarasota County and Englewood Beach located in the southern part of Englewood, Florida in Charlotte County.

Habitat and ecology

The Chadwick Beach Cotton Mouse preferred maritime forests with a closed canopy. Characteristic trees of these forests are *Sabal palmetto*, *Quercus virginiana*, and *Juniperus virginiana* var. silicicola. It was also found on sand dunes where sea oats (*Uniola paniculata*) a high growing grass species is the dominating vegetation. Like the nominate race the Chadwick Beach Cotton Mouse was nocturnal. The ecology of this subspecies is not studied.

Extinction

The Chadwick Beach Cotton Mouse is only known by 15 specimens collected by Luther C. Goldman in March 1938. It is now presumed extinct after extensive surveys in 1984, 1985, 1988 and 1989 failed to find this mouse again. Causes for its disappearance might have been the deforestion of the maritime forests in the southernmost of the Sarasota County as well as the predation by feral cats.

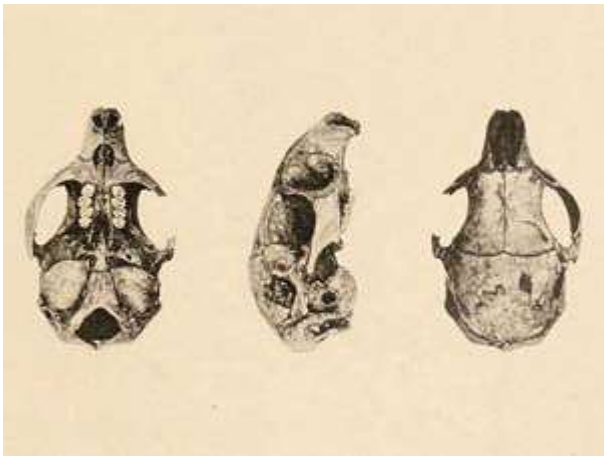
Little Swan Island Hutia

Little Swan Island Hutia

The **Little Swan Island Hutia** (***Geocapromys thoracatus***) is an extinct species of rodent that lived on the Swan Islands, off north-eastern Honduras in the Caribbean. It was a slow-moving, guinea-pig-like rodent and probably emerged from caves and limestone crevices to forage on bark, small twigs and leaves.

It may have been a subspecies of the Jamaican Hutia (*Geocapromys browni*), whose ancestors were carried to the island from Jamaica, 5000-7000 years ago. It was fairly common in the early 20th century, but disappeared after a severe hurricane in 1955, followed by the introduction of house cats to the island.

Torre's Cave Rat



Torre's Cave Rat

Torre's Cave Rat (***Boromys torrei***) was a species of rodent in the Echimyidae family. It was endemic to Cuba. Its natural habitat was subtropical or tropical moist lowland forests.

Bulldog Rat

Bulldog Rat

The **Bulldog Rat** (*Rattus nativitatis*) was a species of rat endemic to the Christmas Island in the Indian Ocean. The rats lived on the higher hills and denser forests of the island. They had short tails and their backs were covered in a two centimetre thick layer of fat. They lived in small colonies, in burrows among the roots of trees or under hollow logs in primary forest. They were sluggish and never climbed and may have seemed half-dazed in daylight. The last record dates from 1903. They may have succumbed to a disease brought by black rats that had been inadvertently introduced by human sailors.

Chapter- 7

Extinct Bats

Puerto Rican Flower Bat

The **Puerto Rican Flower Bat** (***Phyllonycteris major***) is an extinct species of bat from the Phyllostomidae family (leaf-nosed bats). It was endemic to Puerto Rico and is known only from subfossil skeletal material.

Small Mauritian Flying Fox

The **small Mauritian flying fox** or **dark flying fox** (***Pteropus subniger***) is an extinct species of megabat. It lived on the islands of Réunion and Mauritius in the Mascarene Islands of the Indian Ocean. It was abundant, with up to 400 sometimes crowding together at a single roost in a cave or in an ancient, hollow tree, while most other fruit bats prefer to roost in the branches of large trees. Local people believed that there was only one male per roost, which may indicate that the sexes roosted separately and that the large roosts were maternity colonies. The flying fox was nocturnal and had delicate teeth, so it probably fed on nectar and possibly soft fruit.

As it roosted in old trees and caves, it was vulnerable to forest clearance and hunting. It probably vanished in the 19th century. There are specimens in museums in Paris, London, Berlin, and Sydney.

Guam flying fox

The **Guam flying fox** (*Pteropus tokudae*) was a tiny megabat from Guam in the Marianas Islands in Micronesia that was confirmed extinct due to hunting or habitat changes. It was first recorded in 1931 and was observed roosting with the larger and much more common Marianas flying fox. The last specimen was a female found roosting at Tarague cliff in

March 1967, but it escaped capture. An unconfirmed sighting took place in June 1974.No others have been sighted since then.

Dusky Flying Fox

The **Dusky Flying Fox** (***Pteropus brunneus***), also known as the Percy Island Flying Fox, is an extinct species of bat in the Pteropodidae family. It was endemic to Percy Island off the southeast coast of Mackay, Queensland in the northeast corner of Australia.

Only one specimen is known to exist. It was collected in 1859 and documented by Dobson in 1878. Since that record, no further documentation is known of this species. Currently, the specimen is located at the British Museum of Natural History and was validated as a separate species in the late 20th century.

Large Palau Flying Fox

The **Large Palau Flying Fox** (*Pteropus pilosus*) is an extinct species of middle-sized megabat from the Palau Islands in Micronesia. It had brownish fur with long, silvery hairs on its belly, and a wingspan of about 60 cm.. It probably became extinct around 1874, possibly due to overhunting. It is known from two specimens, one of which is in the Natural History Museum in London.

Panay Giant Fruit Bat

The **Panay Giant Fruit Bat** (*Acerodon lucifer*) is a fruit bat from the Philippines that was declared extinct in 1996. Probable causes include anthropogenic destruction of forest habitat and/or overhunting of the species. Many appeared in camps during World War II.

Nendo Tube-nosed Fruit Bat

The **Nendo** or **Santa Cruz Tube-nosed Fruit Bat** (*Nyctimene sanctacrucis*) is an extinct megabat from the Santa Cruz Group of the Solomon Islands, near the eastern limit of the distribution of tube-nosed fruit bats. It had tube-like nostrils and had a wingspan of about 40 cm.

The last record was from the island of Nendo in 1907. The only specimen was a female donated to the Australian Museum, Sydney, in 1892. It may have become extinct due to forest destruction.

New Zealand Greater Short-tailed Bat

The **New Zealand Greater Short-tailed Bat** (*Mystacina robusta*) was one of two species of New Zealand short-tailed bats, a family (Mystacinidae) unique to New Zealand. It lived on the North and South Islands in prehistoric times and historically lived on small islands near Stewart Island/Rakiura. Short-tailed bats were as adept at scrambling along the ground as they were at flying. Their wings folded into pouches on the sides of their bodies, so the bats could race through burrows or scrub. Adult bats reached a length of 9 cm. The only known photograph shows the bat covered in dark blue fur.

The Greater Short-tailed Bat was widespread throughout New Zealand before the Māori arrived. In historic times, it used seabird burrows as roosts. It flew slowly, never rising more than two or three metres above the ground. It took nectar from flowering plants and was probably partly carnivorous, taking meat and fat off muttonbirds and eating nestling birds. The last refuges of the bat were on Solander and Big South Cape islands, but Black Rats arrived from fishing vessels in 1962 or 1963. The last bat seen was caught in a mist net on Solander Island in April 1967.

Lord Howe Long-eared Bat

The **Lord Howe Long-Eared Bat** (*Nyctophilus howensis*) is a species of vesper bat in the Vespertilionidae family. It is known only from a single skull found on Lord Howe Island in 1972 and dated to the 20th century. It may thus be extinct; if not it is certainly endangered.

Sturdee's Pipistrelle

Sturdee's Pipistrelle (*Pipistrellus sturdeei*) is a bat that lived in Japan before officially becoming extinct in 2000.

Range

Pipistrellus studeei is known to have existed only on Hahajima Island in Bonin Islands, Japan. Some experts claim that this species never actually lived in Japan and its locality in Japan is just an error. As a result, the true distribution and origin of this animal is unknown.

Population

The previous population of this animal is unknown because only one specimen has been preserved, which is currently housed in the British Museum of Natural History. There have been no additional records of the Studee's Pipistrelle for over a century.

Chapter- 8

Aurochs

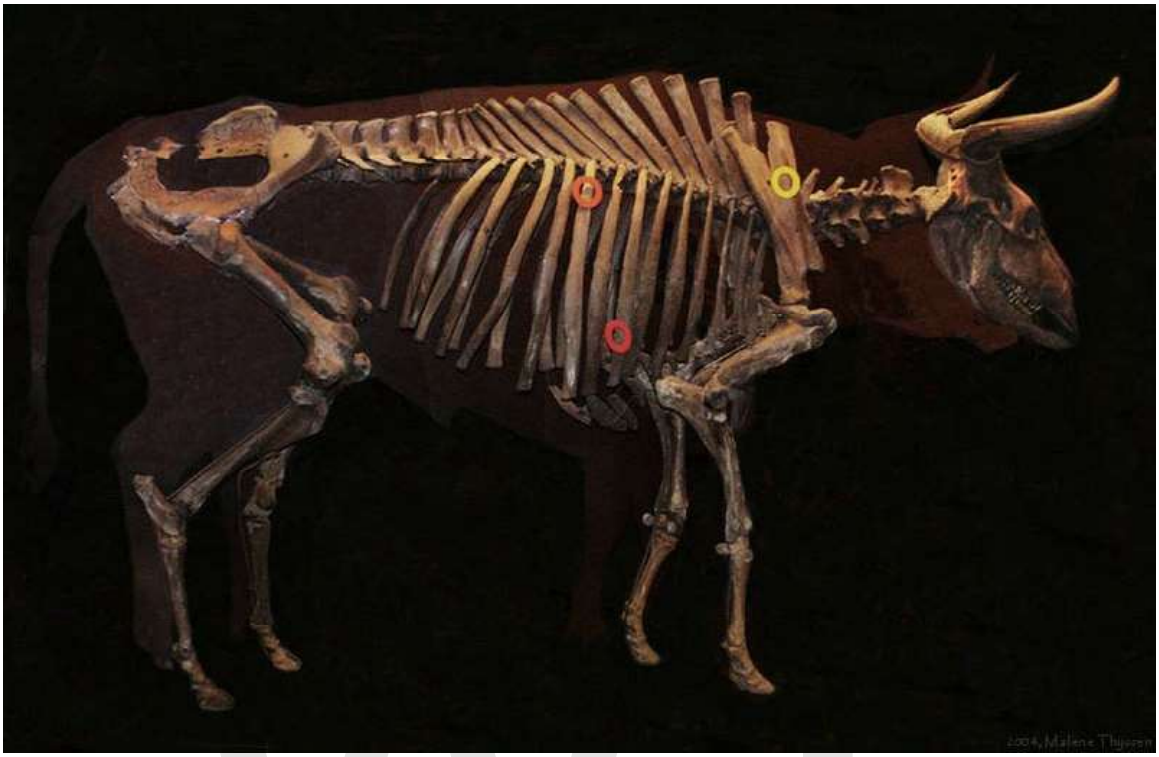
The **aurochs** or **urus** (***Bos primigenius***), the ancestor of domestic cattle, was a type of huge wild cattle which inhabited Europe, Asia and North Africa, but is now extinct; it survived in Europe until 1627.

The aurochs was far larger than most modern domestic cattle with a shoulder height of 2 metres (6.6 ft) and weighing 1,000 kilograms (2,200 lb). The aurochs was regarded as a challenging quarry animal, contributing to its extinction. The last recorded aurochs, a female, died in 1627 in the Jaktorów Forest, Poland, and its skull is now the property of Livrustkammaren in Stockholm.

Aurochs appear in prehistoric cave paintings, Julius Caesar's *The Gallic War* and as the national symbol of many European countries, states and cities such as Alba-Iulia, Kaunas, Romania, Moldavia, Mecklenburg, and Uri. The swiss canton Uri was actually named after this animal species.

Domestication of bovines occurred in several parts of the world but at roughly the same time, about 8,000 years ago, possibly all derived from the aurochs. In 1920, the Heck brothers, who were German biologists, attempted to recreate aurochs. The resulting cattle are known as Heck cattle or Reconstructed Aurochs, and number in the thousands in Europe today. However, they are genetically and physiologically distinct from aurochs. The Heck brothers' aurochs also have a pale yellow dorsal stripe, instead of white.

Nomenclature



This specimen is from around 7500 BC and is one of two very well preserved aurochs skeletons found in Denmark. The Vig-aurochs can be seen at The National Museum of Denmark. The circles indicate where the animal was wounded by arrows.

The words "aurochs", "urus", and "wisent" have all been used synonymously in English. However, the extinct aurochs/urus is a completely separate species from the still-extant wisent.

The animal's original scientific name, *Bos primigenius*, was meant as a Latin translation of the German term *Auerochse* or *Urochs*, which was (possibly incorrectly) interpreted as literally meaning "primeval ox" or "proto-ox". This scientific name is now considered invalid by the Integrated Taxonomic Information System (ITIS), which classifies aurochs under *Bos taurus* – the same species as domestic cattle. In 2003, however, the International Commission on Zoological Nomenclature "conserved the usage of 17 specific names based on wild species, which are pre-dated by or contemporary with those based on domestic forms", confirming *Bos primigenius* for the Aurochs. Taxonomists who consider domesticated cattle a subspecies of the wild Aurochs should use *B. primigenius taurus*; the name *B. taurus* remains available for domestic cattle where it is considered to be a separate species.

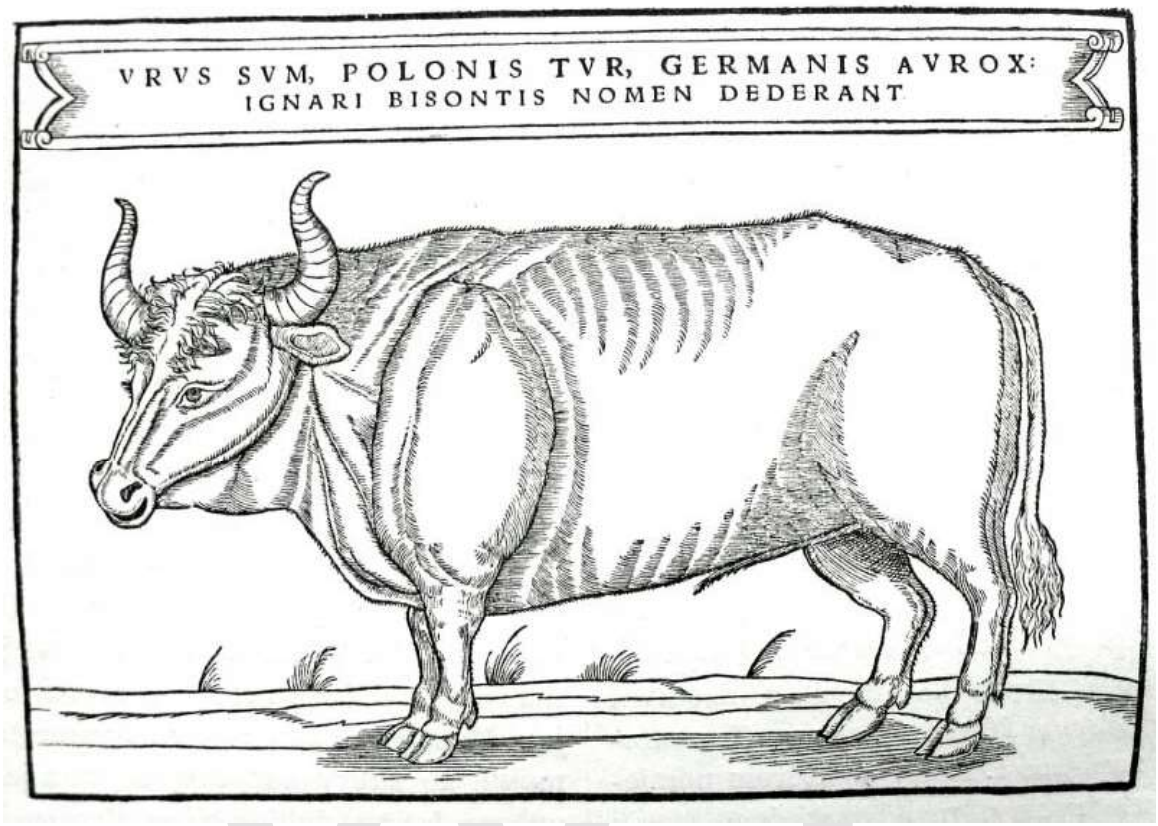


Illustration from Sigismund von Herberstein's book published in 1556 captioned "I'm 'urus', *tur* in Polish, *aurox* in German (dunces call me bison)";
Latin original: *Urus sum, polonis Tur, germanis Aurox: ignari Bisontis nomen dederant*

The word "aurochs" comes to English from German, where its normal spelling and declension today is *Auerochs/Auerochse* (singular), *Auerochsen* (genitive), *Auerochsen* (plural). The declension in English varies, being either "auroch" (singular), "aurochs" (plural) or "aurochs" (singular), "aurochses" (plural). The declension "auroch" (singular), "aurochs" (plural), acknowledged by MWU, is a back-formation analogous to "pea"-from-"pease" derived from a misinterpretation of the singular form ending in the /s/ sound (being cognate to "ox/Ochs(e)"). The use in English of the plural form "aurochsen" is not acknowledged by AHD4 or MWU, but is mentioned in *The Cambridge Encyclopedia of the English Language*. It is directly parallel to the German plural and analogous (and cognate) to English "ox" (singular), "oxen" (plural).

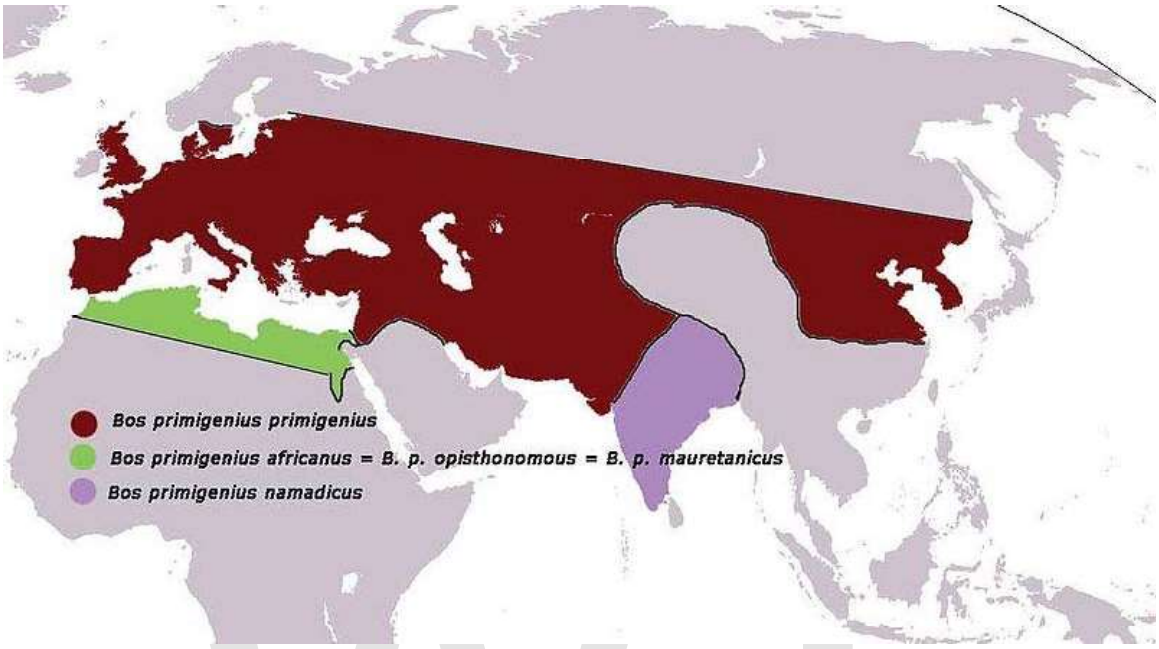
The word "urus" comes to English from Latin, but may have come to Latin from Germanic origins. It declines in English as "urus" (singular), "uruses" (plural).

Origin

An aurochs fighting off a Eurasian Wolf pack

According to the Paleontologisk Museum, University of Oslo, aurochs evolved in India some two million years ago, migrated into the Middle East and further into Asia, and reached Europe about 250,000 years ago. They were once considered a distinct species from modern European cattle (*Bos taurus*), but more recent taxonomy has rejected this distinction.The South Asian domestic cattle, or zebu, descended from a different group of aurochs at the edge of the Thar Desert; this would explain the zebu's resistance to drought. Domestic yak, gayal and Javan cattle do not descend from aurochs. Modern cattle have become much smaller than their wild forebears. Aurochs were about 1.75 metres (5 ft 9 in) tall, while a very large domesticated cow is about 1.5 metres (4 ft 11 in) and most domestic cattle are much smaller than this. Aurochs also had several features rarely seen in modern cattle, such as lyre-shaped horns set at a forward angle, a pale stripe down the spine, and sexual dimorphism of coat color. Males were black with a pale eel stripe or finching down the spine, while females and calves were reddish (these colours are still found in a few domesticated cattle breeds, such as Jersey cattle). Aurochs were also known to have very aggressive temperaments and killing one was seen as a great act of courage in ancient cultures.

Subspecies



Map, after Cis Van Vuure's *Retracing the Aurochs: History, Morphology & Ecology of an Extinct Wild Ox*

Three wild subspecies of aurochs are recognized. Only the Eurasian subspecies survived until recent times.:

- The **Eurasian subspecies** (*Bos primigenius primigenius*) once ranged across the steppes and taigas of Europe, Siberia, and Central Asia. It is part of the famous Pleistocene megafauna, and declined in numbers along with other megafauna species by the end of Pleistocene. The Eurasian aurochs were domesticated into modern taurine cattle breeds around the 6th millennium BC, in the Middle East, and possibly also at about the same time in the Far East. Aurochs were still widespread in Europe by the time of the Roman Empire, when they were widely popular as a battle beast in Roman arenas, and excessive hunting began and continued until it was nearly extinct. By the 13th century, aurochs existed only in low numbers in Eastern Europe, and hunting of aurochs became a privilege of nobles, and later royal households. The decreased hunting did not save the aurochs from extinction, and the last recorded live aurochs, a female, died in 1627 in the Jaktorów Forest, Poland from natural causes.

- The **Indian subspecies** (*Bos primigenius namadicus*), the Indian Aurochs, once lived in the hot and dry areas of India. It was the first subspecies of the aurochs to appear, at 2 million years ago, and from it descends the Eurasian Aurochs and the African Aurochs., and from about 9000 BC it was domesticated as zebu cattle.

- The **North African subspecies** (*Bos primigenius mauretanicus*), the African Aurochs, once lived in the woodland and shrubland of North Africa. It is descended from the Indian Aurochs, which migrated from the Middle East.It is unknown when the North African Aurochs became extinct. Prior to its extinction the Ancient Egyptians may have domesticated the African Aurochs into Egyptian cattle,which was the primary breed of cattle in the Mediterranean regionuntil the introduction of zebu from India, which slowly replaced Egyptian cattle in the region.

Behavioral patterns

The recovery pattern of aurochs remains lead to the belief that they preferred swampy and wet wooded areas and, like modern cattle, could swim for short distances enabling them to inhabit islands within their range. Their diet is thought to have consisted of green grass and leaves with occasional tree fruits. Aurochs species were found to have lived on the island of Sicily where once there was a land bridge to Italy. After disappearance of the land bridge, Sicilian aurochs evolved to a size 20% smaller than their mainland relatives. Although the European bison prefers drier forest they would most certainly have lived in areas overlapping aurochs territory. Little else is known about Aurochs habits. Although they survived until the 17th century in Poland, they were in competition with modern cattle for food and hunted by humans contributing to their extinction.

Genetics

The first complete mitochondrial genome (16,338 base pairs) DNA sequence analysis of *Bos primigenius* from an archaeologically-verified and exceptionally-well preserved aurochs bone sample was published in 2010.

Domestication and extinction

Skull of an aurochs

Monument to the last aurochs in Jaktorów, Poland

The now-extinct aurochs *Bos primigenius*, which ranged throughout much of Eurasia and Northern Africa during the late Pleistocene and early Holocene, is widely accepted as the wild ancestor of modern cattle. Archaeological evidence shows that domestication of this formidable animal occurred independently in the Near East and the Indian subcontinent between 10,000–8,000 years ago, giving rise to the two major domestic taxa observed today — humpless *Bos taurus* (taurine) and humped *Bos indicus* (zebu), respectively. This is confirmed by genetic analyses of matrilineal mitochondrial DNA sequences, which reveal a marked differentiation between modern *Bos taurus* and *Bos indicus* haplotypes, demonstrating their derivation from two geographically- and genetically-divergent wild populations.

Domestication of the aurochs began in the southern Caucasus and northern Mesopotamia from about the 6th millennium BC, while genetic evidence suggests that aurochs were independently domesticated in India and possibly in northern Africa. Domesticated cattle and aurochs are so different in size that they have been regarded as separate species; however, large ancient cattle and aurochs "are difficult to classify because morphological traits have overlapping distributions in cattle and aurochs and diagnostic features are identified only in horn and some cranial element."

Aurochs horn from 200,000 years BP found near Madrid (Spain)

Comparison of aurochs bones with those of modern cattle has provided many insights about the aurochs. Remains of the beast, from specimens believed to have weighed more than a ton, have been found in Mesolithic sites around Goldcliff, Wales. Though aurochs became extinct in Britain during the Bronze age, analysis of bones from aurochs that lived in the same age as domesticated cattle there showed no genetic contribution to modern breeds. As a result of this study, modern European cattle were thought to have descended directly from the Near East domestication. Another study, however, found distinct similarities between modern breeds and Italian aurochs specimens suggesting that the previously-tested British aurochs were not a good model of the diversity of aurochs genetics and suggesting possible North African and European aurochs input to domestic breeds.

Indian cattle (zebu), although domesticated eight to ten thousand years ago, are related to aurochs which diverged from the Near Eastern ones some 200,000 years ago. African cattle are thought to descend from aurochs more closely related to the Near Eastern ones. The Near East and African aurochs groups are thought to have split some 25,000 years ago, probably 15,000 years before domestication. The "Turano-Mongolian" type of cattle now found in Northern China, Mongolia, Korea and Japan may represent a fourth domestication event (and a third event among *Bos taurus*–type aurochs). This group may have diverged from the Near East group some 35,000 years ago. Whether these separate genetic populations would have equated to separate subspecies is unclear.

The maximum range of the aurochs was from Europe (excluding Ireland and northern Scandinavia), to northern Africa, the Middle East, India and central Asia. By the 13th century A.D., the aurochs' range was restricted to Poland, Lithuania, Moldavia,

Transylvania and East Prussia. The right to hunt large animals on any land was restricted to nobles and gradually to the royal household. As the population of aurochs declined, hunting ceased but the royal court still required gamekeepers to provide open fields for the aurochs to graze in. The gamekeepers were exempted from local taxes in exchange for their service and a decree made poaching an aurochs punishable by death. In 1564, the gamekeepers knew of only 38 animals, according to the royal survey. The last recorded live aurochs, a female, died in 1627 in the Jaktorów Forest, Poland from natural causes. The skull was later robbed by the Swedish Army during the Swedish invasion of Poland (1655–1660) and is now the property of Livrustkammaren in Stockholm. The causes of extinction were hunting, a narrowing of habitat due to the development of farming, climatic changes and diseases transmitted by domestic cattle.

Re-creation

Heck cattle

In the 1920s two German zoo directors (in Berlin and Munich), the brothers Heinz and Lutz Heck, began a selective breeding program in the attempt to breed the aurochs back into existence from the domestic cattle that were their descendants. Their plan was based on the concept that a species is not extinct as long as all its genes are still present in a living population. The result is the breed called *Heck cattle*, "Recreated Aurochs", or "Heck Aurochs", which bears some resemblance to what is known about the *appearance* of the wild aurochs.

Scientists of the Polish Foundation for Recreating the Aurochs (PFOT) in Poland want to use DNA from bones in museums to recreate the aurochs and return this animal to the forests of Poland. The project has gained the support of the Polish Ministry of the Environment. They plan research on ancient preserved DNA. Other research projects have extracted "ancient" DNA over the past twenty years and their results published in such periodicals as *Nature* and *Proceedings of the National Academy of Sciences USA*. Polish scientists believe that modern genetics and biotechnology make recreating an animal almost identical to aurochs possible. They say this research will lead to examining the causes of the extinction of the aurochs, and help prevent a similar occurrence with domestic cattle.

In a similar program, Project Tauros is trying to DNA sequence breeds of modern cattle to find gene sequences which match those found in "ancient DNA" from aurochs samples. The modern cattle would then be selectively bred to try to bring the aurochs-type genes back into a single animal. Johan van Arendonk, a professor of animal-breeding and genetics at Wageningen University is quoted as saying, "It's still a very open question if it all can be done."

Art, history, mythology, and media

Aurochs in a cave painting in Lascaux, France.

Sculpture of aurochs (*tarvas*) in Rakvere, Estonia.

Possible version of a Moldavian princely flag in use during the time of Stephen the Great

- Aurochs are depicted in many Paleolithic European cave paintings such as those found at Lascaux and Livernon in France. Early carvings of the aurochs have also been found. The impressive and dangerous aurochs survived into the Iron Age in Anatolia and the Near East, and was worshipped throughout that area as a sacred animal, the Lunar Bull, associated with the Great Goddess and later with Mithras.
- A 1999 archaeological dig in Peterborough, England, uncovered the skull of an aurochs. The front part of the skull had been removed but the horns remained attached. The supposition is that the killing of the aurochs in this instance was a sacrificial act.
- Aurochs are depicted on the Ishtar Gate.
- The ancient name of the Estonian town of Rakvere, *Tarwanpe* or *Tarvanpea*, probably derives from *Auroch's head* (*Tarva pea*) in ancient Estonian. A 3.5m high and 7.1m long Statue of an Aurochs was opened in Rakvere in 2002, for the town's 700th birthday. The sculpture, made by artist Tauno Kangro, has become a symbol of the town.
- The wild-ox called *re'em* (Strong's # 07214) in the Bible (Numbers 23:22 and 24:8, Deuteronomy 33:17, Job 39:9–10, Psalms 22:21, 29:6, 92:10 and Isaiah 34:7) is occasionally associated with the aurochs and has incorrectly been translated as "unicorn" in the past.
- Julius Caesar wrote about aurochs in *Gallic War* Chapter 6.28, "...those animals which are called uri. These are a little below the elephant in size, and of the appearance, color, and shape of a bull. Their strength and speed are extraordinary; they spare neither man nor wild beast which they have espied. These the Germans

take with much pains in pits and kill them. The young men harden themselves with this exercise, and practice themselves in this sort of hunting, and those who have slain the greatest number of them, having produced the horns in public, to serve as evidence, receive great praise. But not even when taken very young can they be rendered familiar to men and tamed. The size, shape, and appearance of their horns differ much from the horns of our oxen. These they anxiously seek after, and bind at the tips with silver, and use as cups at their most sumptuous entertainments."

- An aurochs head, the traditional arms of the German region Mecklenburg, is included in the coat of arms of Mecklenburg-Vorpommern. The aurochs ("bour" in Romanian, probably derived from lat. *bos urus* → *bourus* → *bour*) was also the symbol of Moldavia; nowadays they can be found in the coat of arms of both Romania and Moldova. The horn of the aurochs is a charge of the coat of arms of Tauragė, Lithuania. It is also present in the emblem of Kaunas, Lithuania, and was part of the emblem of Bukovina during its time as a *Kronland* of Austria-Hungary. The Swiss Canton of Uri is named after the aurochs; its yellow flag shows a black aurochs head.
- East Slavic surnames Turenin, Turishchev, Turov, Turovsky originate from the East Slavic name of the species (Tur).
- Turopolje, a large lowland floodplain south of the Sava river in Croatia, got its name after the once abundant aurochs (Croatian: tur).

Chapter- 9

Bluebuck

The **Bluebuck** or **Blue Antelope** (*Hippotragus leucophaeus*), sometimes called **Blaubok**, is an extinct species of antelope, the first large African mammal to disappear in historic times. It is related to the Roan Antelope and Sable Antelope, but slightly smaller than either. It lived in the southwestern coastal region of South Africa savannahs, but was more widespread during the last glacial. It was probably a selective feeder, preferring high-quality grasses.

Europeans encountered the Bluebuck in the 17th century, but it was already uncommon by then. European settlers hunted it avidly, despite its flesh being distasteful, while converting its habitat to agriculture. The Bluebuck became extinct around 1800. There are only four mounted specimens – in museums in Vienna, Stockholm, Paris, and Leiden – along with some bones and horns elsewhere. None of the museum specimens show a blue colour, which may have derived from a mixture of black and yellow hairs.

Bluebuck Drawing of a Bluebuck from 1778 by Allamand, based on the stuffed type specimen.

Characteristics

Illustration of a Bluebuck and a Klipspringer from 1851.

Total length: 250–300 cm (8.2–9.8 ft) (bull); 230–280 cm (7.5–9.2 ft) (cow)

Shoulder height: 100–120 cm (3.3–3.9 ft)

Skull length: 396 mm (15.6 in)

Horn length: 50–61 cm (20–24 in)

Body mass: 160 kg (350 lb)

Eighteenth century travellers provided contradictory descriptions of this species, perhaps because some were embellishing, while others had not actually seen it and were simply repeating hearsay - Peter Kolb in 1719 incorrectly described it as having a long goat-like beard and tail, straight horns like an oryx, and short ears. They did send some skulls and skins back to Europe. In 1967, Erna Mohr reported that the four existing mounted blue antelopes vary from 102 to 116 cm (3.35 to 3.81 ft) at the shoulder. Adult Bluebuck probably rarely exceeded 160 kg (350 lb). None of the four museum specimens show any sheen of blue. The dark skin showing through the thinning fur of older animals may have caused the blue colours described by several authors or the mix of black and yellow hairs.

Like most antelopes, the Bluebuck had six teeth along the cheek in each half of the upper and lower jaws. These formed two distinct series three premolars immediately followed by three molars. Its remains can be distinguished from those of the roan by smaller molars and premolars, and from the sable by larger premolars, and a higher ratio of premolar row length to molar row length.

The Bluebuck was a large, horse-like antelope, as heavy as a Javan or English horse, but smaller than the roan or sable. The proportions of its body were similar to that of the southern reedbuck.

It had a relatively long, strong neck with a very short, underdeveloped mane, long white legs with dark bands on the anterior, and a long tail, up to the hock, with a dark, horse-like whisk. It had a long muzzle. Its ears were long and donkey-like, rufous and narrow-pointed, without the black tufts of hair found in the roan.

The long, scimitar-shaped horns inserted directly above the orbits, extending upwards at almost right angles to the skull , and then curving back gently, without any torsion, towards the shoulders. These horns were heavily ridged, with 20-35 rings up to the tip of the horn, comparable to the roan (20-50 rings). Its horns were however more lightly built than those of the roan and sable, and slightly transversely compressed to the inside. The back-curved horns reminded Jan van Riebeeck of the European ibex, and he called it the 'steinbok'. It remains uncertain how long this name was used, or when it was changed to 'blaauwbok' or Bluebuck.

Its hair was short and glossy, and of a delicate light blue to grey - which quickly faded to a bluish grey after death. Its belly was pale white, and didn't actually contrast with the colour of the flanks. Its forehead and the upper muzzle was brown, becoming lighter towards the cheeks and upper lips. It had distinct white patches in front of the eyes not reaching the white muzzle.

The bulls resembled the cows up to the age of three years, after which they became paler (almost white) and developed large, more curved horns; the horns of the cows where more or less of the same length, although thinner and 10-20% smaller. The calves younger than 2 months were light tan, with no or very indistinct markings.

Range

When the Europeans settled in the Cape Colony in the 17th and 18th century, they found the Bluebuck on the coastal plains of the southwestern Cape Province , east of the Hottentots Holland mountains. It was never very common, and was probably restricted to a grassland area of less than 4 000 km^2 in the triangle formed by the towns of Caledon, Swellendam and Bredasdorp, South Africa. Lieutenant W.J. St. John also recorded 'roans' of a bluish grey colour at Liebenbergsvlei (28º15’S, 28º29’E) near Bethlehem in the Free State Province on 28–29 July 1853, and it is now thought that he actually saw the last remnants of a relict population of Bluebuck.

From archaeological and palaeontological evidence it is known that the Bluebuck had a wider distribution, and was more common, during the early Holocene Epoch 10,000 years ago. At one time it could be found on the coastal plain of the Cape Province from Elands Bay in the northwest to Uniondale in the east. Researchers of the National Museum in Bloemfontein have found San (Bushman) rock paintings near Ficksburg and Golden Gate Highlands National Park , while Pleistocene deposits (100 000 to 10 000 years ago) confirm its existence at Rose Cottage cave near Ladybrand .

Habitat

The early travellers found the Bluebuck only in rolling grassland with extensive marshes and open areas with medium to long (0,5-1,5 m), perennial tuft grass and little hillside shrub. It was also at home at higher elevations, up to 2 400 m above sea-level. It was susceptible to droughts, and water was a necessary habitat requirement.

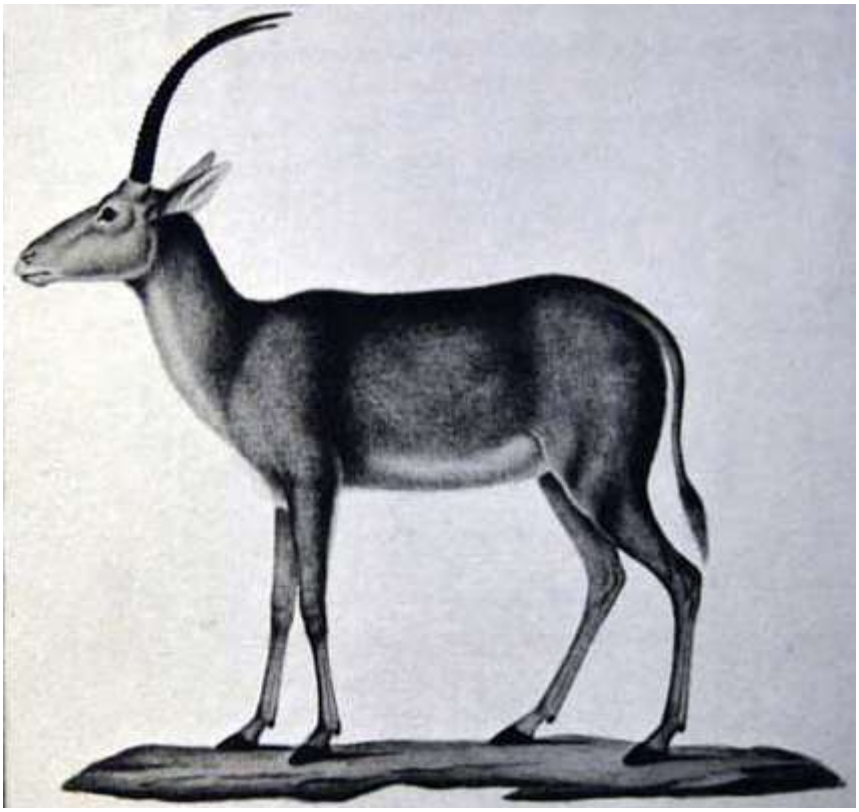
They avoided areas with short grass and woodland where trees formed a thick canopy or thickets. Habitat change, due to overgrazing of grassland by other species, like sheep, thus threatened this species.

Food

Like the roan and sable, it had to drink daily. Many other antelopes can obtain the moisture they need from the plants they eat and they can go for long periods without drinking.

The Bluebuck was a selective grazer of medium to long (0.5-1.5 m), perennial tuft grasses, like high-quality red grass (*Themeda triandra*), spear grass (*Heteropogon contortus*), buffalo grass (*Panicum* spp.) and love grass (*Eragrostis* spp.). Unlike most other antelope, it was not particularly attracted to fresh grass, except during the dry season, when it would graze for short periods along drainage-lines and on floodplains on the fresh growth following the yearly fires. However, like most grazers, it would probably browse during the dry season.

Behavior



Drawing from 1781, by Le Vaillant

Most of its activities took place during the day, especially early in the morning and late in the afternoon.

Bluebucks followed the conventional territorial system among the Hippotragini or 'horse antelopes': territorial bulls, herds of cows and calves, and bachelor herds which were kept segregate by the territorial bulls.

Bluebuck cows and calves lived in small to medium-sized herds of 5 to 20 individuals, although herds of 35 to 80 was not unusual. They normally occurred at a low density of about 4/km^2. Cows shared a traditional home range, which included the territories of several bulls and occupied it for up to 30 years. At very low densities in substandard habitat the cows ranged across larger areas, and were accompanied by the same bull,

which in the absence of resistance by territorial neighbours, defended a movable space around his own private harem.

Because they were equipped with long, dangerous horns, cows tended to be more aggressive than those antelope whose females are hornless. Dominance hierarchies based on age and individual prowess were vigorously maintained by both sexes. Maternal herds, composed of animals that shared the same home range, were closed to outsiders. Herd members kept out of range of each other's horns, by increasing the individual space between them.

Herd composition changed daily and seasonally; members split into small groups during the rainy season, and concentrated into larger groups on the best available grazing near water during the dry season. The most cohesive groups were maintained by calves of different ages, which clustered around the youngest calf and usually lagged behind the herd.

Bulls were accepted in the natal herd up to the age of 15–18 months, which was unusually long. Until then, their similarity to cows suppressed the aggression of the territorial bulls. Subadult bulls were driven from the herd, and if these juveniles didn't escape quickly enough, they were killed. They then joined bachelor herds, where they stayed until they reached five or six years of age, when they would be strong enough to defend their own territory.

The adult bull would advertise his presence and high social status by standing or lying alone or away from the herd, at a conspicuous place. The bull stood in an erect manner, which was a sign of high status, and it was self-advertising if it was not directed. When another bull approached his herd, the dominant bull would stand with his neck arched, head high, and ears turned sideways. Unless the intruder showed submission by lowering his head, the bull kept his ears erect, and waved his tail or tucked it between his legs, and a clash of horns and head-butting would take place. Its sound was a blowing snort.

Reproduction

One calf, with a birth mass of 12–14 kg, was dropped after a gestation period of 268–281 days at any time of the year, with a peak during late summer. Bluebuck are thought to have lived for up to 18 years.

Predators

The calves were vulnerable to attacks from spotted hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*) and wild dogs (*Lycaon pictus*). The adults were large and formidable, and resistant to predation in areas with low predator densities. They did sometimes fall prey to lions (*Panthera leo*), but were attacked with caution. Normally they would flee from predators, but when wounded, a bluebuck would lay down, preferably in a marsh, and defended itself with its razor-sharp horns - the angle-horn threat display indicating that it intended to stab sideways or over its shoulder.

History and population

The Bluebuck or Blue Antelope was the first large African mammal to become extinct in historical times.

Shortly after the last Ice Age, about 10 000 years ago, the Bluebuck must have been common in the far south of Africa, which was largely covered with grassy plains. Numerous finds of subfossil bones indicate a former distribution area from Elands Bay in the present Cape Colony to about 25° E at Uniondale, as well as in the Eastern Free State. Bluebuck numbers dropped about 3 200-2 000 years ago, due to the change of grassland into bush and forest when the climate became warmer.

They showed a sharp decline around 400 A.D., which coincided with the introduction of livestock, particularly sheep, by man at about that time. Competition for grazing with sheep, the resulting habitat degradation due to overgrazing, and diseases may all have contributed to a decline in Bluebuck. Subsistence hunting could also have played a role - it is known that the Late Stone Age inhabitants of Rose Cottage cave hunted several game species, including Bluebuck. To the San (Bushman) the Bluebuck was an important animal, since rock art indicates that these animals contained supernatural power.

Jan van Riebeeck mentioned a "steinbok" or ibex with back-curved horns near Cape Town, while the German Peter Kolb was the first to write about the existence of a "blaauwbok" or Bluebuck in 1719. The Bluebuck was clearly on its way to extinction when European naturalists and hunters finally discovered it. Its range was already small when Europeans who settled in the Cape Colony in the 17th and 18th century first saw this antelope. The Swedish naturalist Carl Peter Thunberg noted in 1774 that these animals were becoming rare. European hunters and farmers hunted it mainly for its skin. Its meat was not fatty, and generally fed to the dogs, although it was just as tasty as that of deer. According to the German zoologist Martin Lichtenstein, the last Bluebuck in the Cape Province was killed in 1799/1800 in the Swellendam district . However, there is good evidence to suggest that an isolated remnant population still existed further north in the 18th century, and that the last Bluebuck died in the Eastern Free State more than fifty years later.

Extinction

A Bluebuck on display in the Naturhistorisches Museum Wien.

Cultivation of the Cape Colony and hunting with firearms quickly destroyed the last small herds. The Bluebuck disappeared before the early natural history cabinets and museums had a chance to obtain a fair number of specimens.

Museum specimens

There are four mounted Bluebuck skins: in the National Museum of Natural History "Naturalis" in Leiden (the Netherlands), and in the natural history museums of Stockholm (Sweden), Paris (France) and Vienna (Austria). Not counting the many bones

excavated throughout the species' former range, there are two skulls, in Amsterdam (the Netherlands) and Glasgow (United Kingdom), and three pairs of horns, in Uppsala (Sweden), London (United Kingdom) and Cape Town (South Africa). None of these specimens are properly documented. .

Relatives

Two close relatives of the Bluebuck are the roan antelope (*Hippotragus equinus*) and the sable antelope (*Hippotragus niger*). Although some naturalists in the past classified the Bluebuck merely as a subspecies of the roan, it is now generally accepted as a separate species. This is based on the fact that Bluebuck and roan occurred in sympatry on the coastal plain of the southwestern Cape from Oakhurst to Uniondale during the early Holocene.

There were a lot of speculations that the Giant or Giant Sable Antelope (*Hippotragus niger variani*) had become extinct. There had been unconfirmed sightings in recent years, but no confirmed sightings for 20 years. This subspecies of the Sable Antelope only occurred in Angola, and there are no specimens present in zoos.

An expedition headed to Angola on 14 August 2002 to search for the giant sable antelope. The expedition had tried hunting for the antelope by helicopter, but the animals avoid sound at all costs. Interviews with tribal chiefs revealed that locals often sighted the animals in the Luando reserve, so the expedition changed tactics and carried out ground surveys on foot. They recorded five separate sightings but were not able to take any photographs. These five animals were spotted in Cangandala National Park in Malanje province in north-central Angola by a team led by Professor Wouter van Hoven of the University of Pretoria.

Chapter- 10

Extinct Artiodactyls

Caucasian Wisent

The **Caucasian Wisent** (*Bison bonasus caucasicus*) was a subspecies of Wisent that inhabited the Caucasus Mountains of Eastern Europe.

It was hunted by the Caspian Tiger and the Asiatic Lion (until 10th century) in the Caucasus, as well as other predators such as wolves and bears.

Caucasian Wisent An image of a killed Caucasian Bison from E. Demidoff's book 'Hunting Trips in The Caucasus' (1889)

Decline and extinction

In the 17th century, the Caucasian wisent still populated a large area of the Western Caucasus. After that human settlement in the mountains intensified and the range of the Caucasian wisent became reduced to about one tenth of its original range at the end of the 19th century. In the 1860s the population numbered still about 2000, but was reduced to

only 500-600 in 1917, and only 50 in 1921. Local poaching continued and in 1927, the three last Caucasian bison were killed .

Hybrid survivors

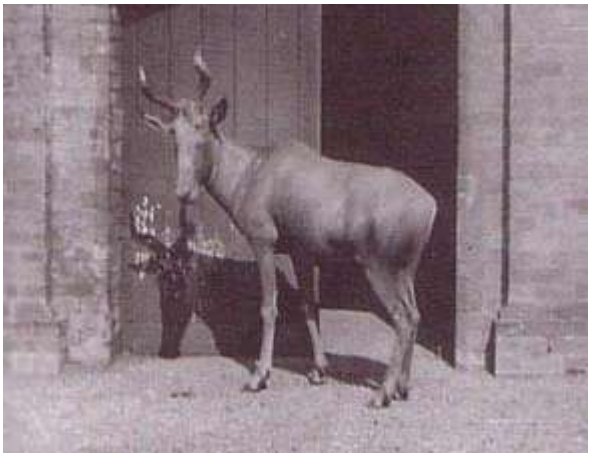
A hybrid in Poznań New Zoo

Only one Caucasian bison bull is known to have been in captivity. This bull, named Kaukasus, was born in the Caucasus Mountains in 1907 and brought to Germany in 1908 where it lived until 26 February 1925. While in captivity it bred with cows from the Lowland subspecies *Bison bonasus bonasus*. Thus it became one of the 12 ancestors of the present Lowland-Caucasian breeding line of the European wisent pedigree book.

Wisent reintroductions in the Caucasus

In 1940, a group of wisent-American bison hybrids were released into the Caucasian Biosphere Reserve and later in 1959 in the Nalchik Forestry Game Management Unit (Kabardino-Balkariya). Later some pure-blood wisent of the Lowland-Caucasian breeding line were released there to form a single mixed herd together with the hybrids. In 2000, these hybrids are described as a different (although questionable) subspecies, the Highland bison *Bison bonasus montanus* .

Bubal Hartebeest



A female Hartebeest that lived in London Zoo from 4 October 1883 until 27 April 1897. Photographed by Lewis Medland in 1895.

The **Bubal Hartebeest** (*Alcelaphus buselaphus buselaphus*) is an antelope that became extinct in 1923.

The name Hartebeest is an Dutch word (originally spelled hertebeest) which means deer. The Bubal Hartebeest stood at around 122 cm (4 ft) at the shoulder. It also had lyre-shaped horns. The Bubal Hartebeest is believed to have once lived in Algeria, Egypt, Libya, Morocco and Tunisia. It may also have resided in the Middle East. The Hartebeest was once domesticated by Egyptians and may have been used as a sacrificial animal. Its horns in tombs at Abadiyeh indicated its importance as a food source and in mythology. It is even mentioned in the Old Testament under the name Yachmur (1 Kings 4:23). Starting in the 1900s the Bubal Hartebeest could only be found in Algeria and the Moroccan High Atlas. French people who resided in Morocco had shot these animals for fun, and for hunting, which kill large herds of them out.Many Hartebeests were captured and were kept alive (e.g. in the London Zoo from 1883 to 1907), but they eventually died out. In 1923, a Bubal Hartebeest female that died in a Paris Zoo is believed to have been that last one remaining.

The Dutch name for the Bubal Hartebeest is Noord-Afrikaans Hartenbeest.

The ancient Egyptians had a hieroglyph meaning "baby hartebeest":

Arabian Gazelle

The **Arabian gazelle** *(Gazella arabica)* was an elusive gazelle that was hunted to extinction in its Middle Eastern homeland, Saudi Arabia. It is only known from a single specimen collected on the Farasan Islands in the Red Sea in 1825. However, it is highly unlikely that the specimen actually originated from the Farasan Islands, and represented a former population on the island. The gazelles now occurring on Farasan Islands are a subspecies of Mountain Gazelle, which was distinguished from this species from skull characteristics. Since the 1996 IUCN Red List of Threatened Species this species is included as extinct by its Antelope Specialist Group until 2008. Since 2008, the *Arabian Gazelle* is rated as Data Deficient due to the unresolved mystery among the validity of this taxon.

Red gazelle

The **red gazelle** (*Eudorcas rufina*) is an extinct species of gazelle, which lived in northern Algeria and Morocco. Some authorities (e.g. Kingdon 1997), however, consider that it was a subspecies of Red-fronted Gazelle (*E. rufifrons*). The red gazelle was formerly considered a member of the genus *Gazella* within the subgenus *Eudorcas* before *Eudorcas* was elevated to genus status.

It probably lived in the better-watered mountain areas of North Africa rather than in deserts, due to the rich colouring on the coat. The last record dated from before 1894. It is known from three specimens, which were purchased in markets in Algiers and Oran, northern Algeria, in the late nineteenth century. They are held in museums in Paris and London.

Schomburgk's Deer

Specimen in West Berlin Zoo

Schomburgk's Deer (*Rucervus schomburgki*) was a member of the family Cervidae. This deer was endemic to Thailand. Schomburgk's deer was described by Edward Blyth in 1863 and named after Sir Robert H. Schomburgk, who was the British consul in Bangkok from 1857-1864.

This deer was a graceful species similar in appearance to the barasingha. The fur was a dark brown with lighter underparts. The underside of the tail was white. Males possessed basketlike antlers, upon which all the main tines branched. This caused the deer to have up to 33 points on their antlers and the outer edge of the rack to be up to 35 inches long. Females had no antlers.

The mounted specimen in Paris

Close up of the head

Schomburgk's deer inhabited swampy plains with long grass, cane, and shrubs in central Thailand, particularly in the Chao Phraya River valley near Bangkok. This deer avoided dense vegetation. They lived in herds that consisted of a single adult male, a few females, and their young. However, during the flooding that occurred during the rainy season, the herds were forced together upon higher pieces of land which could turn into islands. This made them easy targets for hunters.

Commercial production of rice for export began in the late nineteenth century in Thailand leading to the loss of nearly all grassland and swamp areas this deer depended on. Intensive hunting pressure at the turn of the century restricted the species further until it became extinct.

The wild population of Schomburgk’s deer is thought to have died because of overhunting in 1932, with the last captive individual being killed in 1938. The species is also listed as *extinct* in the 2006 IUCN Red List of Threatened Species. However, some scientists consider this species to be still extant. Only one mounted specimen is known to be in existence, which currently resides in Paris's Muséum national d'Histoire naturelle after living in the zoo there until 1868.

In 1991, antlers were discovered in a Chinese medicine shop in Laos. Laurent Chazée, an agronomist with the United Nations, later identified the antlers from a photograph he took as coming from Schomburgk's deer.

Queen of Sheba's Gazelle

The **Queen of Sheba's Gazelle** or **Yemen Gazelle** (*Gazella bilkis*), is an extinct subspecies of the Arabian Gazelle, which is also extinct. It is sometimes regarded as a species in its own right: *Gazella bilkis*. It was found on the mountains and hillsides in Yemen but there have been no sightings of the species since 1951, when five specimens were collected in mountains near Ta'izz, where it was reportedly common at the time.

There have been no further specimens, sightings or reports of this gazelle. Surveys in the area of their former occurrence have failed to find any sign of its presence.

In 1985, a photograph of gazelles was taken in a private collection, Al Wabra Wildlife Farm, in Qatar. Zoologist Colin Groves claims these could possibly be surviving Queen of Sheba's Gazelles. It is not confirmed that these animals truly belong to this species.

Saudi Gazelle

The **Saudi Gazelle**, (*Gazella saudiya*), is an extinct species of gazelle that was once found in the Arabian peninsula. It is extinct due to hunting by humans of its native lands.. It was declared to be extinct in 2008, but it is likely to have disappeared before that.

The Saudi Gazelle once lived in the gravel and sandy plains of North and Western Arabian peninsula. It once occurred widely from Kuwait to Yemen, with most of the records coming from Western Saudi Arabia. The Saudi gazelles are found singly or in groups up to 20.

The Saudi Gazelle was formerly seen as a subspecies of the Dorcas Gazelle, which is why its decline and extinction received so little conversational attention. Recent genetic studies proved its position as a separate species. Apart from genetic differerences, the Saudi gazelle also had shorter legs than and was lighter in color.

The species was always rare and declining due to excessive hunting. The species has not been seen for a few decades, and was declared to be Extinct in the Wild in 1980. Recent genetic analysis of all reported specimens of *G. saudiya* in captive collections has shown that these represent different species or hybrids. There are frequent surveys attempting to find pure Saudi gazelles in private owned gazelles and in the wild, but there have been no evidence of surviving individuals. The Saudi gazelle was officially declared to be Extinct by IUCN in 2008.

Pyrenean Ibex

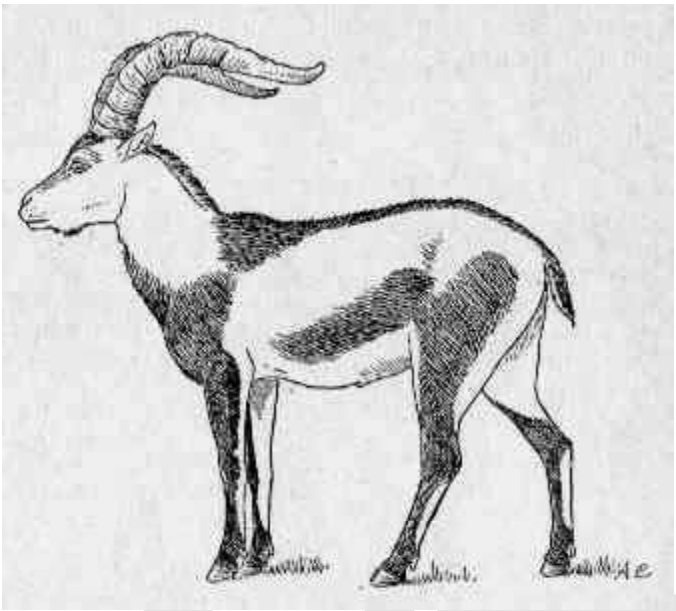
The **Pyrenean Ibex** (*Capra pyrenaica pyrenaica*) is an ibex, one of the two extinct subspecies of Spanish Ibex. The subspecies once ranged across the Pyrenees in France and Spain and the surrounding area, including the Basque Country, Navarre, north Aragon and north Catalonia. A few hundred years ago they were numerous, but by 1900 their numbers had fallen to fewer than 100. From 1910 onwards, their numbers never rose above 40, and the species were found only in a small part of Ordesa National Park, in Huesca.

The last natural Pyrenean Ibex, a female named Celia, was found dead on January 6, 2000, apparently killed by a falling tree. Although her cause of death is known, the reason for the extinction of the subspecies as a whole is a mystery. Some hypotheses include the inability to compete with other species for food, infections and diseases, and poaching. The Pyrenean Ibex became the first taxon ever to become "un-extinct" when, for a period of seven minutes in January 2009, a cloned female Ibex was born alive before dying from breathing difficulties.

Pyrenean Ibex

The diet of the Pyrenean Ibex consisted of grass, herbs and lichens. The ibex was paraxonic, with the plane of symmetry of each foot passing between the third and fourth digits. The third and fourth digits were quite large and bore most of the weight.

Cloning project



Drawing of a Pyrenean Ibex from 1914.

The biotechnology company Advanced Cell Technology, Inc. announced on October 8, 2000 that the Spanish government has agreed to their offer to use nuclear transfer cloning technology in collaboration with other scientific partners to clone the Pyrenean ibex from the tissue that was taken in 1999. It was expected to be easier than the cloning experiment of endangered gaur (*Bos gaurus*), as the reproductive biology of goats is better known and the normal gestation period is only five months. ATC has agreed with the government of Aragon that the future cloned Pyrenean Ibexes will be returned to their original habitat.

The project could be of useful conservation value only if multiple goats could be cloned to form a viable gene pool. As it is, cloning one goat will not save the subspecies.

Celia was able to provide perfect tissue samples for cloning. However, attempts to clone Celia have highlighted a major problem: even if it were possible to produce another healthy Pyrenean Ibex, there are no males for the female clone to breed with. One solution could be to cross Celia's clones with males of another subspecies, although the offspring would not be pure Pyrenean Ibex. A more ambitious plan would be to remove one X chromosome and add a Y chromosome from another still-existing subspecies, creating a male Pyrenean Ibex, but such technology does not yet exist and it is not known whether this will be feasible at all without irreparably damaging the cell.

Three teams of scientists, two Spanish and one French, are involved in the cloning project. The project is coordinated by the Food and Agricultural Investigation Service of the Government of Aragon (Spanish: *Servicio de Investigación Agroalimentaria del Gobierno de Aragón*) and by the National Institute of Investigation and Food and Agrarian Technology (*Instituto Nacional de Investigación y Tecnología Agraria y*

Alimentaria). The National Institute of Agrarian Investigation of France is also involved in the project.

First attempt fails

Researchers took adult Somatic cell from the tissue and fused them with oocytes from goats that had their nucleus removed. The resultant embryos were transferred into a domestic goat (*Capra hircus*), to act as a surrogate mother. In 2003, it was announced that the first attempt to clone the Pyrenean Ibex failed. Of the 285 embryos reconstructed, 54 were transferred to 12 mountain goat and mountain goat-domesticated goat hybrids, but only two survived the initial two months of gestation before they too died.

Later attempt

In 2009, one clone was born alive, but died seven minutes later, due to physical defects in the lungs.

Chapter- 11

Extinct Carnivores

Falkland Islands Wolf

Falkland Islands Wolf Illustration by John Gerrard Keulemans (1842-1912)

The **Falkland Islands Wolf** (*Dusicyon australis*), also known as the **Warrah** and occasionally as the **Falkland Islands Dog**, **Falkland Islands Fox** or **Antarctic Wolf**, was the only native land mammal of the Falkland Islands. This endemic canid became extinct in 1876 (on West Falkland island), the first known canid to have gone extinct in historical times. It was the only modern species in the genus ***Dusicyon***. Original research supposed that the most closely related genus is *Lycalopex*, including the Culpeo and his domestic forms (perro fueguino, perro yagán), which itself has been introduced to the Falkland Islands in modern times. But 2009 research conducted by a scientific team directed by Graham J. Slater, a post-doctoral researcher at the University of California, Los Angeles, confirmed that the Falkland Island wolf's closest living relative is actually the Maned Wolf (*Chrysocyon brachyurus*) - an unusually long-legged, fox-like South

American canid, which it separated from about 6.7 million years ago. It was known from both West and East Falkland, but it is unknown if the varieties were much differentiated.

The fur of the Falkland Islands Wolf had a tawny colour. The tip of the tail was white. The diet is unknown. Due to the absence of native rodents on the Falklands, its diet probably consisted of ground-nesting birds such as geese and penguins, grubs and insects, as well as seashore scavenging. It was sometimes said to have dwelt in burrows.

History

Illustration of "Dusicyon australis" from Zoology of the Voyage of H.M.S. Beagle

The first recorded sighting was by Capt. John Strong in 1692. Captain Strong took one of the animals on his ship, but during the voyage back to Europe the creature became frightened by the firing of the ship's cannon and jumped overboard. Louis Antoine de Bougainville, who established the first settlement in the Falkland Islands termed it a *loup-renard* ("fox-wolf"). The name "warrah" is a corruption of the term *aguará* (meaning "fox" in Guaraní , a Native American language), because of its similarity with the Maned Wolf ("aguará guazú"). The warrah's Latin name translates into 'foolish dog of the south,' because of its apparent lack of fear of people.

When Charles Darwin visited the islands in 1833 he named the species *Canis antarcticus* and described it as common and tame. However, at the time of his visit the animal was

confined to West Falkland and its numbers were in massive decline. He predicted that the animal would join the Dodo among the extinct within "a very few years." The settlers regarded the wolf as a threat to their sheep and organised poisoning and shooting on a massive scale. The absence of forests led to the speedy success of the extermination campaign. This was facilitated by the animal's tameness, as is common in insular species due to the absence of predators - trappers would lure the animal with a chunk of meat held in one hand, and kill it with a knife or stick held in the other. However, it would defend itself occasionally if it needed to, as Admiral George Grey noted when they landed on West Falkland at Port Edgar (Falkland Islands) on December 17, 1836 -

> "I landed in the creek and had hardly put a foot on shore, when one of the foxes of the country was chased by Pilot. I ran up as they were fighting and came to the poor dog's assistance who had nearly met his match, and a rifle ball soon settled the business, but the Pilot had received a terrible bite in the leg."

A live wolf was taken to London Zoo, England in 1868, but survived only a few years. In 1880, post-extinction, Thomas Huxley classified it as related to the Coyote. In 1914, Oldfield Thomas moved it into the genus *Dusicyon*, with the Culpeo and other South American foxes. (These other canids have since been removed to *Lycalopex*.)

Current researchers in 2009, also found that the four Falklands wolf samples that they examined shared a common ancestor at least 70,000 years ago, which suggests that they arrived on the Falkland islands before the end of the last ice age and before humans ever made it into the New World (Graham J. Slater et al. 2009).

Darwin's description

Darwin writing about his 1834 visit to the Falklands in his *Journal and Remarks* (*The Voyage of the Beagle*) has the following to say of *Canis antarcticus* -

The only quadruped native to the island, is a large wolf-like fox, which is common to both East and West Falkland. Have no doubt it is a peculiar species, and confined to this archipelago; because many sealers, Gauchos, and Indians, who have visited these islands, all maintain that no such animal is found in any part of South America. Molina, from a similarity in habits, thought this was the same with his "*culpeu*"; but I have seen both, and they are quite distinct. These wolves are well known, from Byron's account of their tameness and curiosity; which the sailors, who ran into the water to avoid them, mistook for fierceness. To this day their manners remain the same. They have been observed to enter a tent, and actually pull some meat from beneath the head of a sleeping seaman. The Gauchos, also, have frequently killed them in the evening, by holding out a piece of meat in one hand, and in the other a knife ready to stick them. As far as I am aware, there is no other instance in any part of the world, of so small a mass of broken land, distant from a continent, possessing so large a quadruped peculiar to itself. Their numbers have rapidly decreased; they are already banished from that half of the island which lies to the eastward of the neck of land between St. Salvador Bay and Berkeley Sound. Within a very few years after these islands shall have become regularly settled, in all probability

this fox will be classed with the dodo, as an animal which has perished from the face of the earth. Mr. Lowe, an intelligent person who has long been acquainted with these islands, assured me, that all the foxes from the western island were smaller and of a redder colour than those from the eastern. In the four specimens which were brought to England in the Beagle there was some variation, but the difference with respect to the islands could not be perceived. At the same time the fact is far from improbable.

Evolution

When organising his notes on the last stage of the *Beagle* expedition, Darwin wrote of his growing suspicions that the Galápagos Islands mockingbirds and tortoises differed depending on which island they came from:

When I see these Islands in sight of each other, & possessed of but a scanty stock of animals, tenanted by these birds but slightly differing in structure & filling the same place in Nature, I must suspect they are only varieties. The only fact of a similar kind of which I am aware is the constant asserted difference between the wolf-like Fox of East & West Falkland Islds. If there is the slightest foundation for these remarks the zoology of Archipelagoes will be well worth examining; for such facts [would] undermine the stability of Species.

The term "would" was added after the words had been written, suggesting a cautious qualification from his initial bold statement. He later wrote that such facts “seemed to me to throw some light on the origin of species”. It has been speculated that the unusual distribution of this animal (the only other canine species native to oceanic islands are the Island Fox of California, and Darwin's Fox of Chile - but these habitats are not as remote as the Falklands) and some details of the skull suggest that it originally arrived with natives visiting the islands and was kept by them as a pet in a semi-domesticated state. If that is true, the progenitor form from mainland South America would have become extinct during the last Ice Age. DNA analysis of museum specimens have proved rather inconclusive as to the exact relationship of this animal, some even suggesting hybridization (during the domestication process) with a relative or progenitor of the Coyote; it is not known whether this would have been biologically possible. Another possibility is that, during an Ice Age, a land bridge between Falkland Islands and South America enabled its ancestors to traverse the distance. At any rate, the Falkland Island Wolf is a biogeographical mystery.

According to a study published in 2009 in the journal *Current Biology*, the Falkland Islands Wolf's closest living relative is the South American Maned Wolf. In the same study it is claimed that DNA evidence points to a common ancestor 6 million years ago. This is an interesting date, since canids did not appear in South America until roughly 3 million years ago in a paleozoogeographical event called the Great American Biotic Interchange, in which the continents of North and South America were connected by the formation of the Isthmus of Panama. The lineages of the Maned Wolf and the Falkland Islands Wolf would thus have diverged already in North America. In any case the results of the study rule out the previous hypotheses of introduction by natives. An earlier study,

published in 2003, on the brain anatomy of several canids placed the Maned Wolf and the Falkland Islands Wolf together, and with zorros of the genus *Pseudalopex* as well, on the ground of their unique morphology of the brain sulci and the prorean gyrus.

Commemorations

Locations:

- Fox Bay, a bay and settlement on West Falkland
- Warrah River, West Falkland

Sea Mink

The **Sea Mink**, ***Neovison macrodon***, is an extinct North American member of the Mustelidae family. It is the only mustelid, and one of only two terrestrial mammal species in the order Carnivora, to go extinct in historic times (along with the Falkland Islands Wolf). The body of the sea mink was significantly longer than that of the closely related American Mink (*N. vison*), and also bulkier, leading to a pelt that was almost twice the size of the other species. The longest specimen recorded was said to be 82.6 cm (32.5 in). The fur of the Sea Mink was said to be coarser and redder than the American Mink's, and produced a distinctive odor.

Habitat

It was found along the rocky coasts of New England and Atlantic Canada, as far north as Nova Scotia. It was not a truly marine species, being confined to coastal waters. The Labrador Duck, with which it co-existed, may have been a prey item.

Extinction

Due to its highly prized fur, this mink was hunted to extinction. The animal's remains are often found in Native American shell-heaps around the coasts of the islands of Maine, but while indigenous hunting may have made some contribution to the Sea Mink's decline, it was the competitive European fur trade that led to its extinction.

The last known member of the species was said to have been captured in New Brunswick, Canada, in 1894, although there is some debate if this was a specimen of *N. macrodon* or *N. vison*. The last substantiated report has led to an estimated extinction date of around 1860, although a specimen was reported as sold to a fur-buyer in Maine in 1880.

Although well known to fur hunters, it became extinct before being scientifically described, and therefore little is known about its habits. Existing data suggests it was nocturnal and solitary.

Subspecies

The Sea Mink is sometimes considered a subspecies of the American Mink, in which case the name ***Neovison vison macrodon*** is used.

Japanese Sea Lion

†Japanese Sea Lion

The **Japanese Sea Lion** (*Zalophus japonicus*) is thought to have become extinct in the 1950s.

Prior to 2003 it was considered to be a subspecies of California Sea Lion as *Zalophus californianus japonicus*. However, it was subsequently reclassified as a separate species. Some taxonomists still consider it as a subspecies of the California Sea Lion. It has been argued that *japonicus*, *californianus*, and *wollenbaeki* are distinct species because of their distant habitation areas and behavioral differences.

They inhabited the Sea of Japan, especially around the coastal areas of the Japanese Archipelago and the Korean Peninsula. They generally bred on sandy beaches which were open and flat, but sometimes in rocky areas.

Currently, several stuffed specimens can be found in Japan and the National Museum of Natural History, Leiden, the Netherlands, brought by Philipp Franz von Siebold. The British Museum possesses a pelt and 4 skull specimens.

Physical description

Male Japanese Sea Lions were dark grey and weighed up to 450 to 560 kg reaching lengths of 2.3 to 2.5 meters; these were larger than male California Sea Lions. Females were significantly smaller at 1.64 meters long with a lighter colour than the males.

Range and habitat

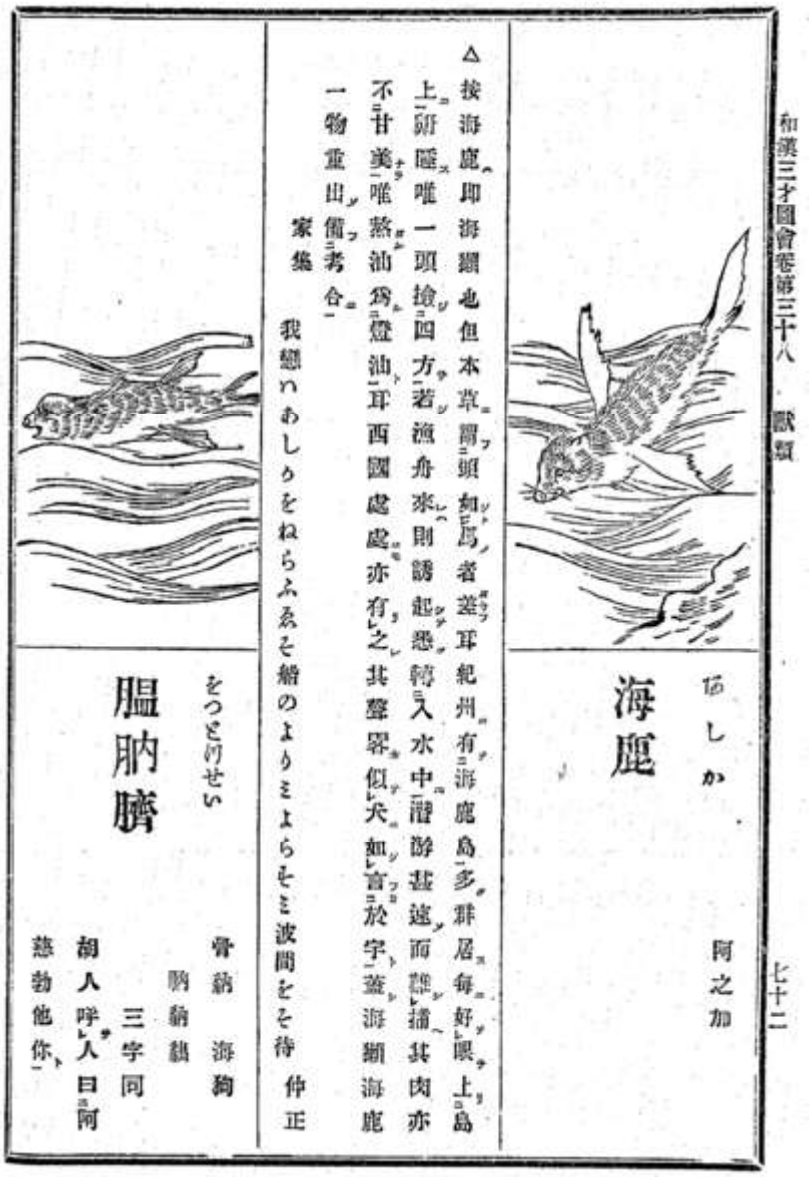
Japanese Sea Lions were primarily found in the Sea of Japan along the coastal areas of the Korean Peninsula, the mainlands of the Japanese Archipelago (the both sides on the Pacific Ocean and Sea of Japan), the Kuril islands, and southern tip of the Kamchatka Peninsula.

Old Korean accounts also describe that the sea lion and Spotted Seal (*Phoca largha*) were found in broad area containing the Bo Hai, the Yellow Sea, and Sea of Japan. The sea lions and seals left a lot of relevant place names all over the coast line of Japan such as Ashika-iwa (アシカ岩, sea lion rock) and Inubosaki point (犬吠崎, lit. dog-barking point) because of the similarity of their howls.

Lifestyle and reproduction

They usually bred on flat, open and sandy beaches but rarely in rocky areas. Their preference was to rest in caves.

Human uses



Sea lion (right) and fur seal, Wakan Sansai Zue (ca. 1712)

Many bones of Japanese Sea Lion have been excavated from shell middens in Jōmon period in Japan while an 18th century encyclopedia, *Wakan Sansai Zue*, describes that the meat was not tasty and they were only used to render oil for oil lamps. Valuable oil was extracted from the skin, its internal organs were used to make expensive oriental medicine, and its whiskers and leathers were used as pipe cleaners and leather goods, respectively. At the turn of the 20th century, they were captured for use in circuses. There were unconfirmed reports that Korean soldiers in World War II stationed at Liancourt Rocks used the sea lions for target practice.

Extinction

Harvest records from Japanese commercial fishermen in the early 1900s show that as many as 3,200 sea lions were harvested at the turn of the century and overfishing caused harvest numbers to fall drastically to 300 sea lions by 1915 and to few dozen sea lions by the 1930s. Commercial harvest of Japanese sea lions ended in the 1940s when the species became virtually extinct. In total, Japanese trawlers harvested as many as 16,500 sea lions, enough to cause their extinction. It is even believed that submarine warfare during World War II contributed to their habitat destruction. The last colony of sea lions sighted were by Korean coast guards in the 1950s with the last confirmed record of *Z. japonicus* being a juvenile captured in 1974 off the coast of Rebun Island, northern Hokkaido.

Population revival efforts

The South Korean Ministry of Environment initiated an effort to search for and reintroduce sea lions to their native habitat in the Sea of Japan. The National Institute of Environmental Research of Korea was commissioned to conduct feasibility research for this project. In 2007, a joint research venture between North Korea, South Korea, Russia, and China was announced. Chinese and Russian waters will be searched for surviving sea lion populations, with hopes of reintroducing the animal to their native habitat. If the animal cannot be found, the South Korean government plans to relocate California sea lions from the United States. The South Korean Ministry of Environment supports the effort because of the symbolism, national concern, the restoration of the ecological system, and possible ecotourism.

Caribbean Monk Seal

Caribbean Monk Seal

The **Caribbean Monk Seal** or **West Indian Monk Seal** (*Monachus tropicalis*) is an extinct species of seal. It is the only seal ever known to be native to the Caribbean sea and the Gulf of Mexico. The last verified recorded sighting occurred in 1952 at Serranilla Bank. On June 6, 2008, after five years of futile efforts to find or confirm sightings of any Caribbean monk seals, the U.S. government announced that the species is officially extinct and the only seal to vanish due to human causes.

A collection of Caribbean Monk Seal bones can be found at the Tropical Crane Point Hammock Museum in Key Vaca.

Physical appearance

The Caribbean Monk Seal was a relatively large seal (1.8-2.7 m) with rolls of fat around its neck and brown pelage that faded to a yellow-white color on the stomach. The soles and palms were naked, with the nails on the anterior digits well developed. The males reached a length of about 3.25 meters and weighed up to 200 kilograms. Displaying sexual dimorphism, the females of this species were generally smaller than males.

Behavior and ecology

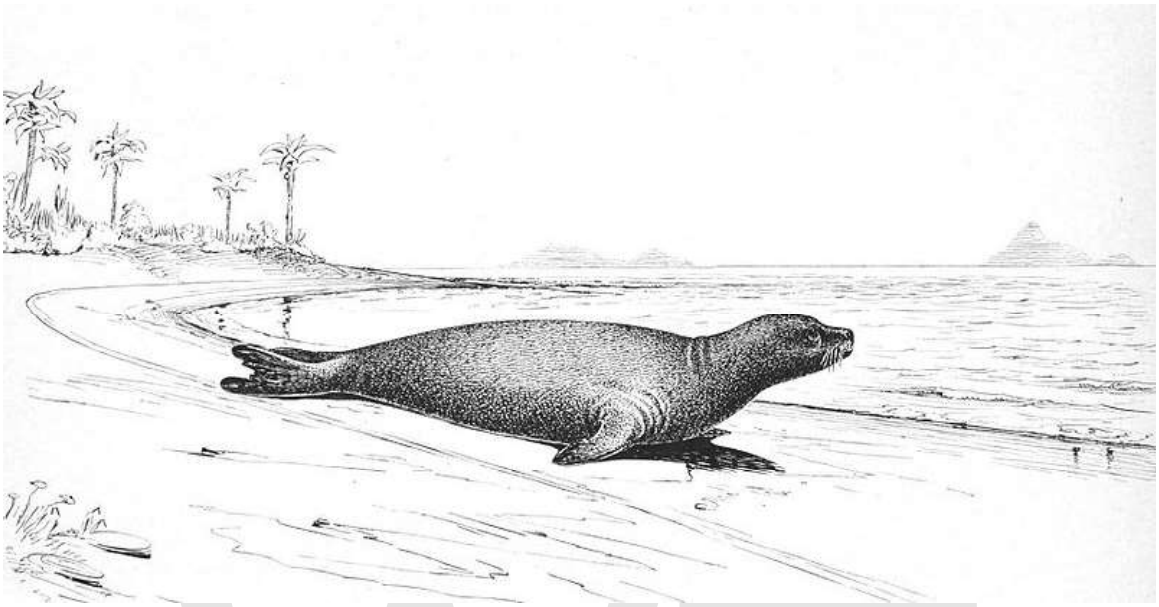
These pinnipeds lived in the marine environment, spending much of their time in the water and occupying rocky and sandy coastlines for shelter and breeding. Their diet included lobsters, octopi, and reef fish.

Like other true seals, the Caribbean Monk Seal was sluggish on land. Its lack of fear for man and an unaggressive and curious nature also contributed to its demise.

Reproduction and longevity

Very little is known about the reproduction behavior and longevity of this animal. Live pups were likely born in early December because several females killed in the Yucatan during this time of the year had well-developed fetuses. It is believed that this animal's average lifespan was approximately twenty years.

History



Drawing of *Monachus tropicalis*.

During his 1494 voyage, Christopher Columbus described the Caribbean Monk Seal as a "sea-wolf." During that voyage, eight seals were killed for their meat. The region was soon colonized, and whatever habitat this species had was lost. People also began exploiting it commercially for its oil, and less frequently, for its meat. It became extinct in the 1950s from lack of food.

Sightings

In the United States, the last recorded sighting of this marine mammal occurred in 1932 off the Texas coast. The very last reliable records of this species are of a small colony at Serranilla Bank between Honduras and Jamaica in 1952.

Unconfirmed sightings of Caribbean Monk Seals by local fishermen and divers are relatively common in Haiti and Jamaica, but two recent scientific expeditions failed to find any sign of this animal. It is possible that the mammal still exists, but some biologists strongly believe that the sightings are of wandering Hooded Seals, which have been positively identified on archipelagos such as Puerto Rico and the Virgin Islands. On April 22, 2009, The History Channel aired an episode of *Monster Quest* which hypothesized that an unidentified sea creature videotaped in the Intracoastal Waterway of Florida's southeastern coast could possibly be the extinct Caribbean Monk Seal. No conclusive evidence has yet emerged in support of this contention, however, and opposing hypotheses asserted the creature was simply a misidentified, yet common to the area, West Indian Manatee.

Bali Tiger

Bali Tiger

The **Bali Tiger** (*Panthera tigris balica*), ***harimau Bali*** in Indonesian, or referred to as ***samong*** in archaic Balinese language, was a subspecies of Tiger which was found solely on the small Indonesian island of Bali. This was one of three sub-species of tiger found in Indonesia, together with the Javan Tiger, which is also extinct, and the critically endangered Sumatran Tiger. It was the smallest of the Tiger subspecies.

The last specimen definitely recorded was a female shot at Sumbar Kima, west Bali, on September 27, 1937. However it is thought likely a few animals survived into the 1940s and possibly 1950s. The sub-species became extinct because of habitat loss and hunting. Given the small size of the island, and limited forest cover, the original population could never have been large.

Characteristics

Size

Old male of the Bali tiger

The Bali Tiger was the smallest of all eight Tiger subspecies, rather comparable with the Leopard or Cougar in size. The weight of a male Tiger was usually 90-100 kg (198-221 pounds); that of a female was 65-80 kg (142-175 pounds). The male was approximately 220 cm (7.2 feet or 86.6 inches) in length (together with tail), and the female 195-200 cm (6.4-6.6 feet, 76.8-78.7 inches).

Appearance

Bali Tigers had short fur that was a deeper, darker orange and had fewer stripes than other tiger subspecies. Occasionally, between the stripes, there were small black spots. Bali tigers also had unusual bar-shaped patterns on the head.

Diet

They preyed upon most mammals that lived within their habitat. Their major sources of food were Wild Boar, Rusa Deer, Indian Muntjac, Red Junglefowl, monitor lizards, monkeys and possibly Banteng (the last now also extirpated on the island). The only known predators of Bali Tigers were humans.

Reproduction

Bali Tigers have an average gestation period of 103 days. They give birth to two or three cubs per litter. The average birth weight of a cub is two or three pounds. They are born blind and helpless. Cubs are weaned at roughly one year of age, and are fully independent at 18 months to 2 years of age. Bali Tigers live approximately 8-10 years.

Relationship to the Javanese tiger

There are two common theories regarding the divergence of Balinese and Javan tigers. The first idea suggests that the two subspecies developed when Bali became isolated from Java by formation of the Bali Strait by rising sea levels after the ice age. This split the tigers into two groups which then went on to develop independently.

The second possibility is that the tiger swam from one island to colonize the other. The Bali Strait is only 2.4 kilometers wide, making it well within the swimming ability of the average tiger. Whichever it was, the two went on to become quite different.

Documentation, hunting and tiger culture in Bali

The hunting party of Baron Oskar Vojnich with a Balinese tiger, shot at Gunung Gondol, NW Bali, Nov. 1911

In Balinese culture, the tiger had a special place in folk tales and traditional arts, like in the *Kamasan* paintings of Klungkung kingdom. However, they were perceived as a destructive force and culling efforts were encouraged all the way to the time of extinction.

Very few reliable accounts of encounters and even fewer visual documentations remain. One of the most complete records was left by the Hungarian baron Oszkár Vojnich, who trapped, hunted and took photos of a Balinese tiger. On November 3, 1911 he shot dead an adult specimen in the northwest region, between Gunung Gondol and Banyupoh River, documenting it in his book "In The East Indian Archipelago" (Budapest 1913).

According to the same book, the preferred method of hunting tigers in the island was catching them with a large, heavy steel foot trap hidden under bait (goat or muntjak) and then killing them with a firearm at close range.

A final blow to the island's already low tiger population came during the Dutch colonial period, when shikari hunting trips were conducted by European sportsmen coming from Java, armed with high powered rifles and a romantic but disastrous Victorian hunting mentality. Surabayan gunmaker E. Munaut is confirmed to have killed over twenty Bali tigers in only a few years.

A Balinese tiger shot in 1925, hunting party unknown, likely European hunters with Javanese trackers

The last confirmed tiger sighting was of an adult female, killed on Sep. 27, 1937, at Sumbar Kima, in western Bali. Since then, claims of sighting have been made, but without proof, mostly by forestry officers, in 1952, 1970 and 1972. It is likely that any remaining tigers were pushed to the western side of the island, mostly into area that is now West Bali National Park, established in 1947.

The Balinese tiger was never captured alive on film or motion picture, or displayed in a public zoo, but a few skulls, skins and bones are preserved in museums. The British Museum in London has the largest collection with two skins and three skulls; others include Senckenberg Museum in Frankfurt, Naturkunde Museum in Stuttgart, Naturalis museum in Leiden and Zoological Museum of Bogor, Indonesia, which owns the remnants of the last known Balinese tiger. In 1997 a skull emerged from the old collection of Hungarian Natural History Museum and was scientifically studied and properly documented.

Unlike stag hunting, which they mastered, very few, if any, Balinese embraced tiger hunting before the arrival of Europeans to the island, because tigers were seen as evil, dangerous creatures. Still, tigers had a well defined position in folkloric beliefs and magic. For example, the Balinese considered the ground powder of tiger whiskers to be a potent and undetectable poison for one's foe. According to the same book mentioning this, Miguel Covarrubias's "Island Of The Gods", 1937, when a Balinese baby was born he was given a protective amulet necklace with black coral and "a tiger's tooth or a piece of tiger bone".

Like in other Asian nations, Balinese people are fond of wearing tiger parts as jewelry for status or for spiritual reasons, like power and protection. Necklaces of teeth and claws or male rings cabochoned with polished tiger tooth ivory still exist in everyday use. Since tigers have disappeared on both Bali and neighboring Java, old parts have been recycled,

or leopard and sun bear body parts have been used instead. One of the traditional Balinese dances, the Barong, still preserves in one of its four forms, a type called the Tiger Barong (Barong Macan).

Caspian Tiger

A captive Caspian Tiger, Berlin Zoo 1899

The **Caspian tiger**, also known as the **Persian tiger**, **Turanian tiger**, **Mazandaran tiger** or **Hyrcanian tiger** was found in Iran, Armenia, Azerbaijan, Iraq, Afghanistan, Turkey, Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan until it apparently became extinct in the late 1950s, though there have been several alleged sightings of the tiger in the more recent years. First thought to have been its own distinct subspecies, genetic research in 2009 proved that the animal was closely related to the Siberian tiger (*P. t. altaica*). Separated by only one letter of genetic code, it is believed that the two split off from each other only in the past century. Some researchers suggest that it may be possible to reintroduce the closely related Siberian Tiger to the Caspian tiger's historical range in hopes of recreating this now-extinct big cat.

Characteristics

Color-enhanced photo of the captive specimen in the Berlin Zoo, 1899

Size

The Caspian tiger's body was generally less massive than that of its Far Eastern cousins, and its average size slightly less. In Turkestan, male tigers exceeded 200 cm in length, though an estimated body length of 270 cm was recorded. Females were smaller in size, normally ranging between 160–180 cm. The maximum known weight was 240 kg. Maximum skull length in males was 297.0-365.8 mm, while that of females was 195.7-255.5 mm. Although tigers from Turkestan never reached the size of the Siberian tiger, there are records of very large individuals of the former population. On January 10, 1954, a tiger killed on the Sumbar in Kopet-Dag had a skull length of 385 mm, which is considerably more than the known maximum for this population and slightly exceeds that of most Far Eastern tigers, though tigers in Manchuria have been recorded as having larger skulls of 406 mm in length.

Pelage

Skin of a tiger from Iran

The main background colour of its pelage varied, though generally, it was brighter and more uniform than that of Far Eastern tigers. The stripes were narrower, fuller and more closely set than those of the Siberian tiger. The colour of its stripes were a mixture of brown or cinnamon shades. Pure black patterns were invariably found only on the head, neck, the middle of the back and at the tip of the tail. Angular patterns at the base of the tail were less developed than those of the Far Eastern populations. The contrast between the summer and winter coats was sharp, though not to the same extent as in Far Eastern populations. The winter coat was paler, with less distinct patterns. The summer coat had a similar density and hair length to that of the Bengal tiger, though its stripes were usually narrower, longer and closer set.

Habitat

In the southeast Trans-Caucasus, the Caspian tiger was mostly confined to the forests of the Talysh lowlands in areas where streams and reed thickets along marine lagoons were adjacent. In Turkmenistan, Uzbekistan and Tajikistan, the tiger favored river and lake basins, densely grown reeds, plume grass or tugai forests consisting of poplar, oleaster and willow. The Caspian tiger was sometimes encountered in montane belts, in summer ascending up to the permanent snowling in Kazakhstan and Kyrgyzstan. Tigers were captured in fir and juniper groves at heights of 2,500-3,000 meters above sea level in Kygryz, Trans-Ili and Dzhunarsk Alatau mountains. Generally, the Caspian tiger thrived

in areas with an abundance of wild boar and Bactrian deer, large water supplies, dense thickets and low snow cover.

Diet

In the southeast Trans-Caucasus, the Caspian tiger's main prey was wild boar, though it occasionally fed on roe deer, red deer and domestic animals such as dogs and cattle in winter. Tigers in Iran ate the same species with the addition of gazelle. The Caspian tiger's prey in Turkmenistan, Uzbekistan and Kazakhstan was primarily boar, as well as Bactrian deer. In the lower Amu-Darya River, tigers sometimes preyed on jackals, jungle cats and locusts. On the Zhana-Darya and around the Aral Sea in Kazakhstan, as well as boar, the tiger fed on saiga, goitered gazelle, wild horses, Mongolian Wild Ass and mountain sheep. In Tajikistan and other regions of central Asia, as well as Kazakhstan, tigers frequently attacked dogs, horses and rarely camels. In Baikal, the Caspian tiger fed on wild boar, caucasian wisent, roe deer, Manchurian wapiti, moose and livestock. Like the Siberian tiger, the Caspian tiger rarely became a man-eater, unlike the Bengal tiger.

Genetics

New genetic analysis revealed that the extinct Caspian tiger lives on in the Siberian Tiger (*Panthera tigris altaica*). Researchers from the University of Oxford in the United Kingdom collected tissue samples from 20 Caspian tiger specimens kept in museums across Eurasia. Afterwards, researchers from the U.S. National Cancer Institute (NCI) Laboratory of Genomic Diversity in Frederick, Maryland, sequenced parts of five mitochondrial genes. The Caspian Tiger's mitochondrial DNA is only one letter of genetic code separated from Siberian Tiger DNA, while it is readily distinguishable from the DNA of other tiger subspecies. This indicates that the Caspian and the Siberian subspecies are really one. The scientists have concluded that the two are so similar because both were descended from the same migrating ancestor. The ancestor colonized Central Asia via the narrow Gansu Corridor (Silk Road) from eastern China. The researchers suggest that through the early 20th century, Caspian and Siberian tiger populations intermingled, but hunters subsequently isolated the two groups. This resulted in the Siberian population splitting off from the Caspian population only in the past century.

History and possible extinction

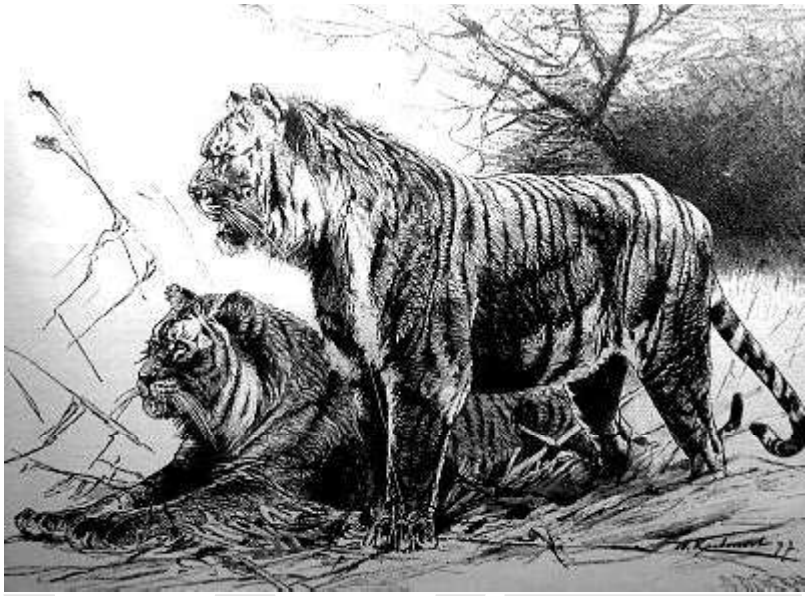


Illustration of two Caspian tigers.

Original distribution of the Caspian tiger

Until the 19th century, Caspian tigers still inhabited wide spaces of Western and Central Asia. In the mid-19th century, Caspian tigers were killed 180 km northeast of Atbasar, Kazakhstan and as far North as near Barnaul, Russia (Ognev 1935, Mazák 1981). The only reported Caspian tiger from Iraq was killed near Mosul in 1887 (Kock 1990). In 1899, the last Caspian tiger near the Lop Nur basin in Xinjiang, China, was killed (Ognev 1935). Caspian tigers disappeared from the Tarim River basin in Xinjiang, China, by the 1920s. (Nowell & Jackson 1996) In 1922, the last known tiger in the Caucasus region was killed near Tbilisi, Georgia, after killing domestic livestock (Ognev 1935). The last record of the Caspian tiger on the Ili River, their last stronghold in the region of Lake Balkhash, Kazakhstan, dates to 1948. (Nowell & Jackson 1996)

The Russian government had worked heavily to eradicate the Caspian tiger during planning a huge land reclamation program in the beginning of the 20th century. They considered there was no room for the tiger in their plans and so instructed the Russian army to exterminate all tigers found around the area of the Caspian Sea, a project that was carried out very efficiently. Once the extermination of the Caspian tiger was almost complete, the farmers cleared forests and planted crops like rice and cotton. Due to intensive hunting and deforestation, the Caspian tiger retreated first from the lush lowlands to the forested ranges, then to the marshes around some of the larger rivers, and finally, deeper into the mountains, until it almost certainly became extinct. In 1938, national park Tigrovaya Balka was opened in Tajik SSR to save Riparian forests and rare animals, including Caspian Tiger, but it didn't help the population of tigers. It was the last stronghold of the Caspian tiger in the Soviet Union. Tigrovaya Balka national park is situated in Tajikistan in the undercurrent of Vakhsh River between the Piandj and Kafirnighan near the border of Afghanistan. The last Caspian Tiger was seen there in 1958.

Some reports state that the last Caspian tiger was shot in Golestan National Park (Iran) or in Northern Iran in 1959 (Vuosalo 1976). However, other reports claim that the last Chinese Caspian tigers disappeared from the Manasi River basin in the Tian Shan mountains, west of Ürümqi, China, in the 1960s. (Nowell & Jackson 1996) The last record from the lower reaches of the Amu Darya river near Lake Aral was an unconfirmed observation near Nukus in 1968 while tigers disappeared from the river's lower reaches and the Pyzandh Valley once a stronghold, in the Turkmen-Uzbek-Afghan border region by the early 1970s (Heptner and Sludskii 1972). (Nowell & Jackson 1996) There are even claims of a documented killing of this subspecies at Uludere, Hakkari in Turkey during 1970 (Üstay 1990; Can 2004). Some reports even state that the final Caspian tiger was captured and killed in Northeast Afghanistan in 1997.

The most frequently quoted date is the late 1950s, but has almost no evidence to back it up. It appears this date came to be accepted after being quoted by H. Ziaie in "*A Field Guide to the Mammals of Iran*". Now, the most evidence reflects an even earlier date of extinction. The area of Iran that contained the last Caspian tigers was in fact the eastern region of Mazandaran, Northern Iran. According to E. Firouz in "*A Guide to the Fauna of Iran, 1999*", the last tiger was killed in 1947 near Agh-Ghomish Village, 10 km East of Kalaleh, on the way to Minoodasht-Bojnoord. An exact date of extinction is unknown.

According to unanimous scientific opinion, the Caspian tiger, as a distinct population has been extinguished irreversibly. According to the confirmed official data and supported by the scientific researches (Hepter and Slutskiy, 1972)during 1900-1968 there were 9 tigers killed in Kopet Dag Mountains. According to scientists (Dement'yev and Rustamov) the last tiger was killed on 10 January 1954 at surrundings of Kone-Kosir in the valley of Sumbar River in Kopet Dag Mountains.

Sightings and doubts about extinction

Possible Turkish last sighting

The following excerpts are taken from "Can, O.E. 2004. Status, Conservation and Management of Large Carnivores in Turkey. Council of Europe. 29 pages. Strasbourg, France".

> "Earlier in the 20th century, the presence of the Caspian tiger had been known by Turkish (Turkish Republic Official Gazette, 1937). Yet, when the Caspian tiger was declared extinct in the world, international zoologists did not accept the idea that the Caspian tiger distribution range extended as far as eastern Turkey (Dr. George Schaller, Ankara, Turkey, personal communication, 2003). In fact, the species was officially a pest species until July 11, 2004 in Turkey. In the 1970s, surveys conducted by Paul Joslin in Iran turned up no signs of the Caspian tiger and the conclusion was made that the Caspian tiger had been extirpated. International cat experts only became aware of the presence of the Caspian tiger in Turkey after a tiger was killed in Uludere, Şırnak 1970 (Uludere was a sub-province of Hakkari in 1970). Three years later, a botanist visiting the area saw and photographed the tiger pelt and published the story (Baytop, 1974)."

Turkish scientists, during a study on the field, reached some information on the presence of the Caspian tiger.

> "Within the framework of Southeastern Anatolia Biodiversity Research Project of WWF-Turkey, a survey was conducted to reveal the large mammal presence and distribution in the region (Can & Lise, 2004). Within the framework of the first attempt to collect systematically the large mammal data in Southeastern Turkey. First, a questionnaire was designed and distributed to 450 military posts in the region. The questionnaire included questions about the presence of large mammal species and each questionnaire was accompanied with Turkey's Mammal Poster of Turkish Society for the Conservation of Nature (which became WWF-Turkey later). The questionnaires were filled out by military personnel in cooperation with the local people and 428 questionnaires were returned to WWF-Turkey. The questionnaires also included questions related with the historical tiger presence in the region. Later, the questionnaire results were used to identify the areas on which the field survey will focus.
> The questionnaire revealed that some military personnel had heard rumors about the presence of large cats in the region. During the interviews with local people, the mammal team collected rumors about big cat sightings and met local people that claimed to hear roaring from different sites. In addition, it was reported that there was a local tiger pelt trade in the region and three to five tigers were killed in each year and the pelts were sold to rich land lords in Iraq until the mid-1980s. This confirms Turan's findings (1984,) who obtained his information from local hunters in the region. Baytop (1974) similarly reported that 1-8 tigers were killed each year in the Þõrnak region.

> Considering that one to eight tigers were killed each year in Eastern Turkey until the mid 1980s, the tiger that was killed in Uludere was a young individual according to the stripe patterns. The Caspian tiger is likely to have existed in the region at least until the early 1990s. Nevertheless, due to lack of interest in addition to security and safety reasons, trained biologists had not attempted to survey in Eastern Turkey before."

While these anecdotal sightings do not prove that the Caspian tiger survived, researchers believe they should investigate this possibility seriously. An investigation was planned for sometime in 2006.. No such investigation has yet been made.

Reported sightings

There are still occasional claims of the Caspian tiger being sighted, with some occurring in Afghanistan, pug marks [tiger paw prints] have occasionally been reported, and others coming from the more remote forested areas of Turkmenistan. However, experts have been unable to find any solid evidence to substantiate these claims and the last reliable sighting was probably at least 30 years ago. It has also been suggested that the 'tiger' sightings may actually be Persian Leopards. Any hope of Caspian tigers in Afghanistan could be further dashed as war continues to rage across areas of the country.

Without photographic evidence, expert assessment of pug marks, attacks on animals or people, or a sighting by an expert authority, there is presently no good reason to believe that the Caspian Tiger still lives. Nonetheless, complete resolution of the matter will probably not be achieved until some time in the late first decade of the 21st century, given the need to investigate the Turkish reports.

Russia-Iran re-population project

Iranian and Russian ecologists are planning a joint project intended to return Caspian Tigers and Asiatic Cheetahs to the wild in the Central Asian region, as the latest genetic studies have shown that the amur tiger is related and virtually identical to the now extinct Caspian Tigers; hence the Russians want to offer it to Iran to repopulate its former range in northern Iran in exchange for critically endangered Asiatic Cheetahs that Russia wants to acquire from Iran to repopulate the northern Caucasus region of central Asia. However, although there are many more Amur Tigers in the wild than the tiny numbers of surviving Asiatic cheetahs, and while there is a healthy population of amur tiger in the captive breeding program in the zoos there is no captive breeding population of the Asiatic Cheetah in any zoo. While discussing the prospects of reintroducing the cheetah in India the cheetah experts from the world over have already warned that no individuals from the critically low Asiatic cheetah population in Iran should be withdrawn at this stage for any reintroduction experiment elsewhere, like the one proposed by Russia in exchange for the more abundant Russian Tiger, as the limited gene pool of Asiatic cheetah in Iran will suffer a tremendous blow.

In 2010, Russia exchanged 2 captive Amur tigers for Persian Leopards with the Iran Government, as conservation groups of both countries have agreed on restocking these animals back into the wild within the next 5 years. Some experts, however, doubt the plan as they feel that this is a political publicity exercise. Unfortunately the male Siberian tiger died in Tehran Zoo on 3rd of January 2011.

Javan Tiger

Javan Tiger

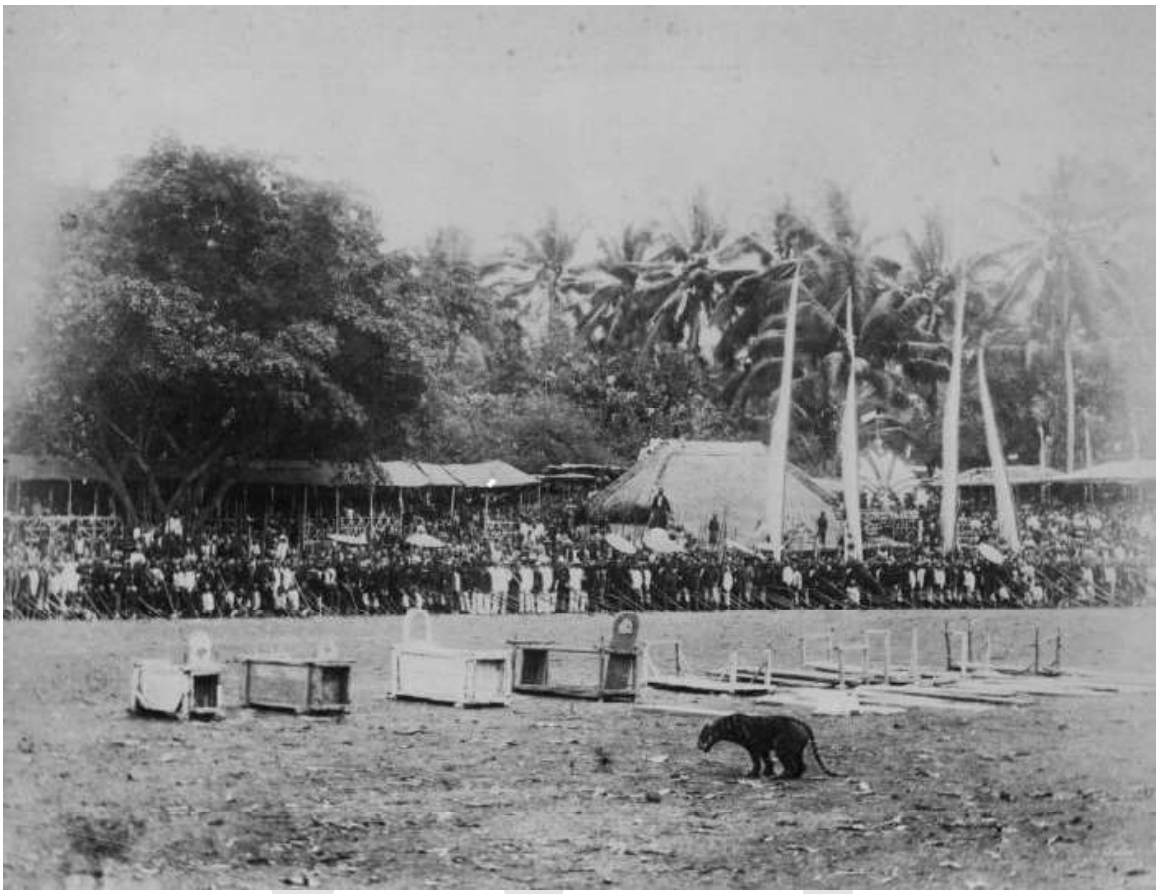
Javan tiger photographed by Andries Hoogerwerf in Ujung Kulon National Park, 1938

The **Javan tiger** (*Panthera tigris sondaica*) is an extinct tiger subspecies. It inhabited the Indonesian island of Java until the 1980s and was one of the three subspecies limited to islands.

Description

avan tigers were very small compared to other subspecies of the Asian mainland, but larger in size than Bali tigers. Males weighed between 100 and 140 kg (220 and 310 lb) on average with a body length of 200 to 245 cm (6.6 to 8.04 ft). Females were smaller than males and weighed between 75 and 115 kg (170 and 250 lb) on average.
Their nose was long and narrow, occipital plane remarkably narrow and carnassials

relatively long. They usually had long and thin stripes, which were slightly more numerous than of the Sumatran Tiger.



Tiger fight in Java, 1870-1892

A group of men and children poses with a recent killed tiger in Malingping in Banten, West-Java, 1941

At the beginning of the 20th century 28 million people lived on the island of Java. The annual production of rice was insufficient to adequately supply the growing human population, so that within 15 years 150% more land was cleared for cultivating rice. In 1938 natural forest covered 23% of the island. 1975 only 8% forest stand remained; the human population had increased to 85 million people. In this human-dominated landscape the extirpation of the Javan Tiger was a process intensified by the conjunction of several circumstances and events:

- Tigers and their prey were poisoned in many places during the period when their habitat was rapidly being reduced;
- Natural forests were increasingly fragmented after World War II for plantations of teak, coffee and rubber, which was unsuitable habitat for wildlife;
- Rusa deer, the tiger's most important prey species, was lost to disease in several reserves and forests during the 1960s;
- During the period of civil unrest after 1965 armed groups retreated to reserves, where they killed the remaining tigers.

Last efforts

Until the mid-1960s tigers survived in three protected areas, which had been established during the 1920-1930s: Ujung Kulon, Leuwen Sancang and Baluran. But following the period of civil unrest no tigers were sighted there any more. In 1971 an older female was shot in a plantation near Mount Betiri in the southeast of Java. Since then not a single cub has been recorded in this last known refuge of the big cats. The area was upgraded to a wildlife reserve in 1972, at which time a small guard force was established and four habitat management projects initiated. The reserve was severely disrupted by two large plantations in the major river valleys, occupying the most suitable habitat for the tiger and its prey. In 1976, tracks were found in the eastern part of the reserve, suggesting the presence of 3-5 tigers. Only a few banteng survived close to the plantations, but tracks of rusa deer, the preferred prey of the Javan tiger, were not sighted.

After 1979, there were no more confirmed sightings of tigers in Meru Betiri. In 1980, Seidensticker and Suyono recommended extending the wildlife reserve and completely eliminating the disruptive influence of humans on the fragile ecosystem. The Indonesian Nature Conservation Authority implemented these recommendations in 1982 by gazetting the reserve as a national park. These measures were however too late to save the few remaining tigers in the region.

In 1987, a group of 30 students of the *Indonesian Agricultural University of Bogor* (Institut Pertanian Bogor) conducted an expedition to Meru Betiri National Park. In groups of five they searched the complete area and found tiger scat and tracks.

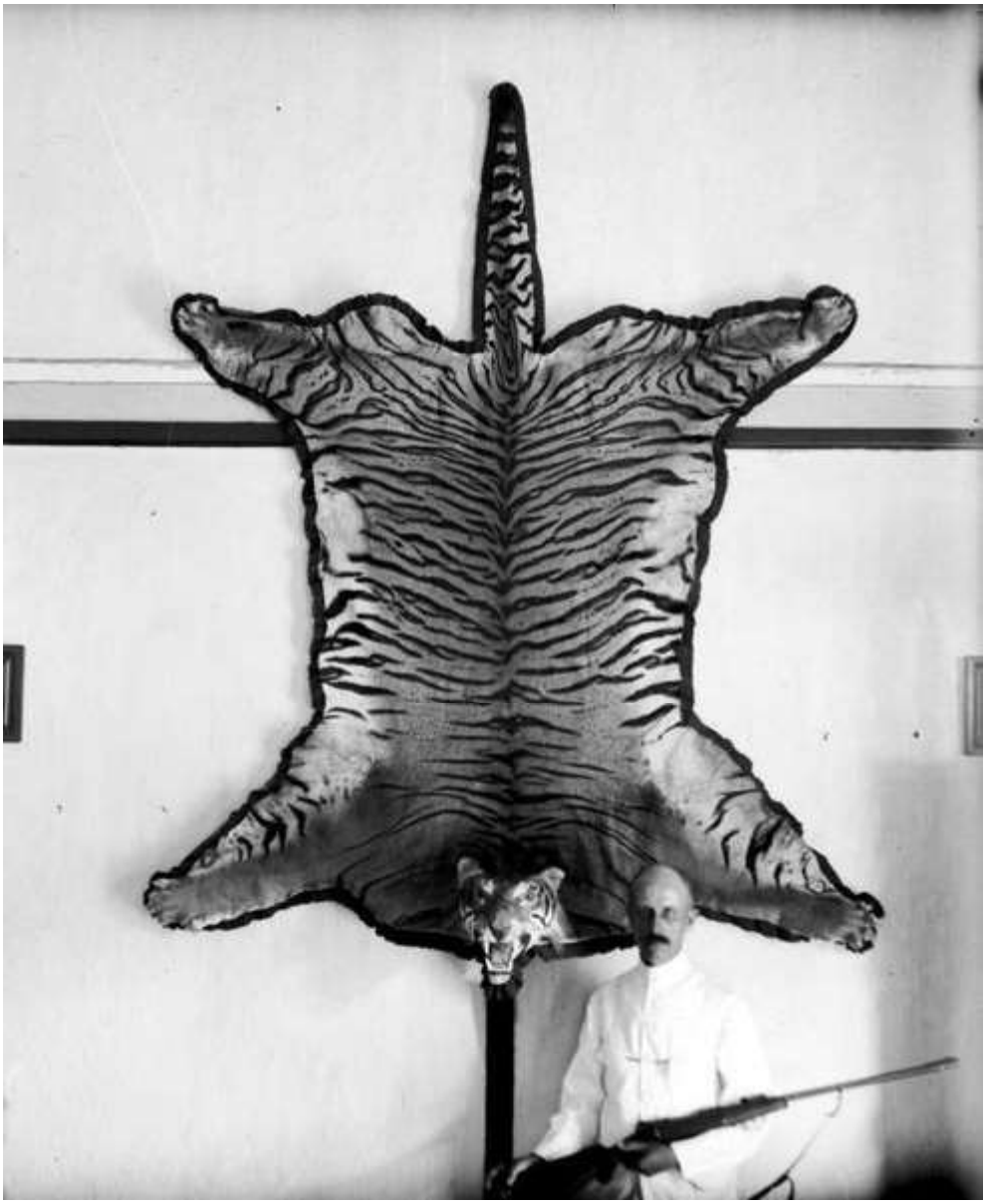
In the West of Java lies the Halimun Reserve, today integrated into the Mount Halimun Salak National Park. In 1984, a tiger was killed there; and in 1989, pugmarks were found that were the size of a tiger's. However, an expedition of six biologists conducted in 1990 did not yield any definite, direct evidence for the existence of tigers.

A subsequent survey was planned in the Meru Betiri National Park in autumn 1992 with the support of WWF Indonesia, deploying camera traps for the first time. From March 1993 to March 1994 cameras were positioned at 19 sites, which did not yield a single picture of a tiger. During this period, no tracks indicating the presence of tigers were discovered. After the final report of this survey had been published, the Javan tiger was declared extinct.

Rumours and indications of the possible presence of tigers in the Meru Betiri National Park prompted the park's Chief Warden *Bapak Indra Arinal* to initiate another search. With support of the *Sumatran Tiger Project*, twelve members of the park staff were trained in autumn 1999 to set up camera traps and map their observations. The Canadian *The Tiger Foundation* provided infrared cameras. Despite a year of work, they photographed no tigers, few prey, and lots of poachers.

Banteng: bulls of the Javan subspecies *Bos javanicus javanicus* are black

Rusa deer from the islands offshore Ujung Kulon have been resettled in Meru Betiri.



Skin of Java tiger, 1915

Occasional reports still surface of enthusiasts who believe that the tiger still exists in Java.

Despite the continuing claims of sightings it is far more likely that, even with full protection and in reserve areas, the Javan tiger has been extirpated. The 'tigers' are quite likely to be leopards seen from a distance.

In November 2008, an unidentified body of a female mountain hiker was found in Mount Merbabu National Park, Central Java, allegedly died from tiger attack. Villagers who discovered the body have also claimed some tiger sightings in the vicinity.

Another recent sighting occurred in Magetan Regency, East Java, in January 2009. Some villagers claimed to see a tigress with two cubs wandering near a village adjacent to Lawu Mountain. This news immediately triggered mass panic. A subsequent investigation by local authorities found several fresh tracks in the location. However, by that time, those animals were already gone.

Following the October 2010 eruption of Mount Merapi, two Indonesian villagers have claimed sightings of a big cat paw print in the residual ash, which sparked rumours a tiger or leopard was roaming abandoned farms in search for food. Personnel of the near-by national park did not think it likely that this paw print was a tiger's.