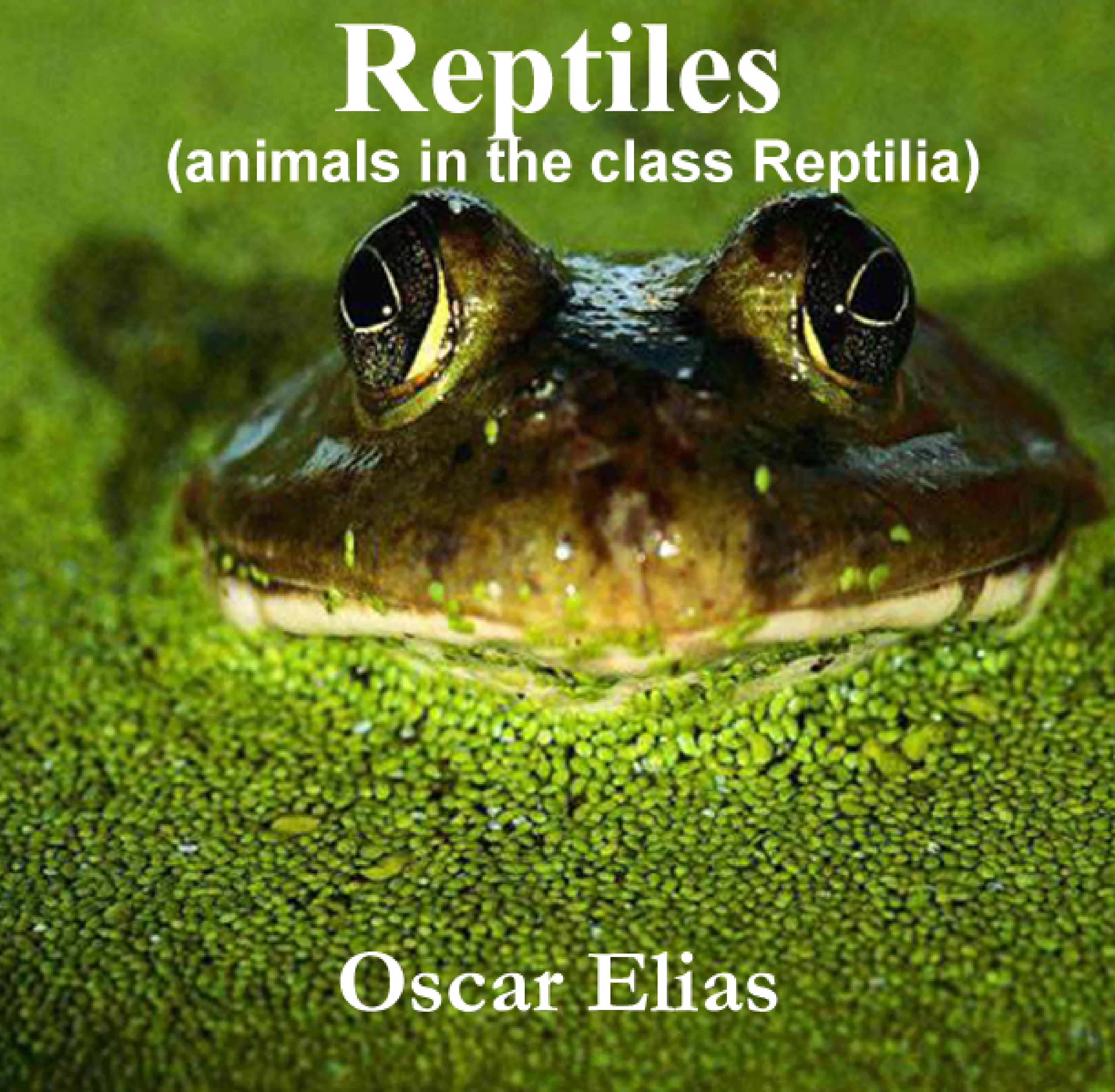
Reptiles

(animals in the class Reptilia)



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Reptile

Reptiles Temporal range: Mississippian - Recent 320–0 Ma	

Clockwise from above left: Spectacled Caiman (*Caiman crocodilus*), Green Sea Turtle (*Chelonia mydas*), Tuatara (*Sphenodon punctatus*) and Eastern Diamondback Rattlesnake (*Crotalus adamanteus*).

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Superclass:	Tetrapoda
(unranked):	Reptiliomorpha
(unranked):	Amniota
Class:	**Reptilia** Laurenti, 1768
Subgroups	

- Anapsida (=Parareptilia?)
    - Testudines (traditional)
- Eureptilia
    - Crocodilia
    - Sphenodontia
    - Squamata
    - Testudines (molecular)

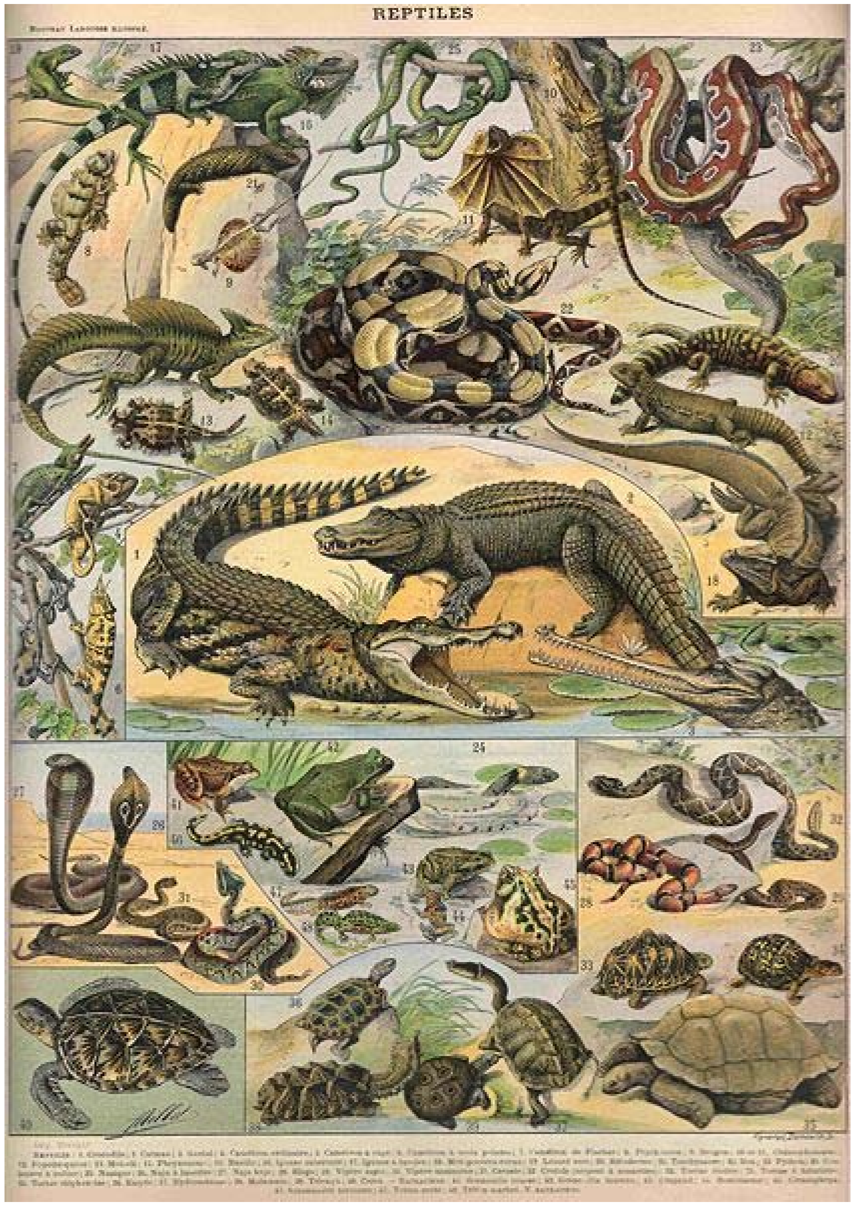
Reptiles are animals in the (Linnaean) class Reptilia. They are characterized by breathing air, laying shelled eggs, and having skin covered in scales and/or scutes. Reptiles are classically viewed as having a "cold-blooded" metabolism. They are tetrapods (either having four limbs or being descended from four-limbed ancestors). Modern reptiles inhabit every continent with the exception of Antarctica, and four living orders are currently recognized:

- Crocodilia (crocodiles, gavials, caimans, and alligators): 23 species
- Sphenodontia (tuataras from New Zealand): 2 species
- Squamata (lizards, snakes, and worm lizards): approximately 7,900 species
- Testudines (turtles and tortoises): approximately 300 species

Contrary to amphibians, reptiles do not have an aquatic larval stage. As a rule, reptiles are oviparous (egg-laying), although certain species of squamates are capable of giving live birth. This is achieved by either ovoviviparity (egg retention) or viviparity (birth of offspring without the development of calcified eggs). Many of the viviparous species feed their fetuses through various forms of placenta analogous to those of mammals, with some providing initial care for their hatchlings. Extant reptiles range in size from a tiny gecko, *Sphaerodactylus ariasae*, that grows to only 1.6 cm (0.6 in) to the saltwater crocodile, *Crocodylus porosus*, that may reach 6 m in length and weigh over 1,000 kg. The science dealing with reptiles is called herpetology.

Classification

History of classification



Reptiles, from *Nouveau Larousse Illustré*, 1897-1904

Linnaeus and the 18th century

The reptiles were from the outset of classification grouped with the amphibians. Linnaeus, working from species-poor Sweden, where the common adder and grass snake are often found hunting in water, included all reptiles and amphibians in class "III – Amphibia" in his Systema Naturæ. The terms "reptile" and "amphibian" were largely interchangeable, "reptile" (from Latin *repere*, "to creep") being preferred by the French. Josephus Nicolaus Laurenti was the first to formally use the term "Reptilia" for an expanded selection of reptiles and amphibians basically similar to that of Linnaeus. It is today stil common to treat the two groups under the same heading as herptiles.

The "Antediluvian monster"

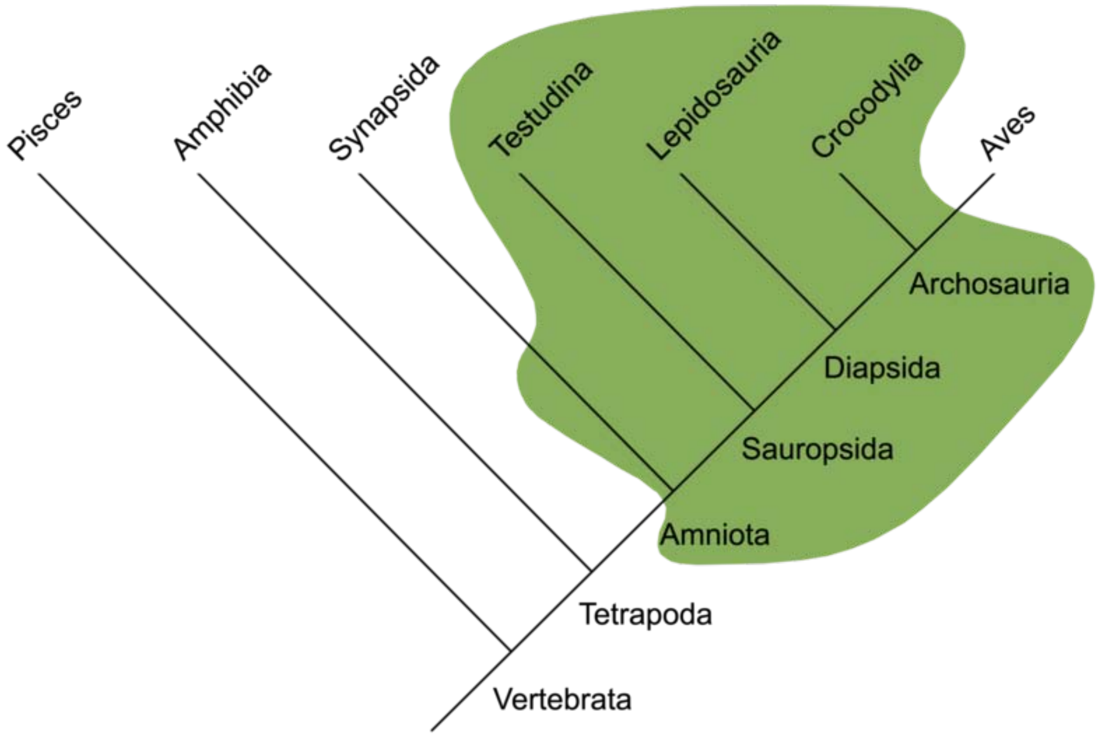
An "Antediluvian monster", a *Mosasaurus* discovered in a Maastricht limestone quarry, 1770 (contemporary engraving)

Not until the beginning of the 19th century did it become clear that reptiles and amphibians are in fact quite different animals, and Pierre André Latreille erected the class *Batracia* (1825) for the latter, dividing the tetrapods into the four familiar classes of reptiles, amphibians, birds and mammals.

The British anatomist Thomas Henry Huxley made Latreille's definition popular, and together with Richard Owen expanded Reptilia to include the various fossil “Antediluvian monsters”, including dinosaurs and the mammal-like (synapsid) *Dicynodon* he helped describe. This was not the only possible classification scheme: In the Hunterian lectures delivered at the Royal College of Surgeons in 1863, Huxley grouped the vertebrates into Mammals, Sauroids, and Ichthyoids (the latter containing the fishes and amphibians). He subsequently proposed the names of Sauropsida and Ichthyopsida for the two.

The terms "Sauropsida" ("lizard faces") and "Theropsida" ("beast faces") were used again in 1916 by E.S. Goodrich to distinguish between lizards, birds, and their relatives on the one hand (Sauropsida) and mammals and their extinct relatives (Theropsida) on the other. Goodrich supported this division by the nature of the hearts and blood vessels in each group, and other features such as the structure of the forebrain. According to Goodrich, both lineages evolved from an earlier stem group, the Protosauria ("first lizards") which included some Paleozoic amphibians as well as early reptiles.

In 1956 D.M.S. Watson observed that the first two groups diverged very early in reptilian history, and so he divided Goodrich's Protosauria between them. He also reinterpreted the Sauropsida and Theropsida to exclude birds and mammals, respectively. Thus his Sauropsida included Procolophonia, Eosuchia, Millerosauria, Chelonia (turtles), Squamata (lizards and snakes), Rhynchocephalia, Crocodilia, "thecodonts" (paraphyletic basal Archosauria), non-avian dinosaurs, pterosaurs, ichthyosaurs, and sauropterygians.



Reptiles (green field) are a paraphyletic group comprising all non-avian and non-mammalian amniotes.

In 1866, Haeckel demonstrated that vertebrates could be divided based on their reproductive strategies, and that reptiles, birds and mammals were united by the amniotic egg. By the end of the 19th century, the class Reptilia had come to include all the amniotes except birds and mammals. Thus reptiles were defined as the set of animals that includes the extant crocodiles, alligators, tuatara, lizards, snakes, amphisbaenians, and turtles, as well as fossil groups like dinosaurs, synapsids and the primitive pareiasaurs. This is still the common definition of the term.

Skull openings in 20th century classification

The synapsid/sauropsid division supplemented, but was never as popular during the 20th century as a Linneaean approach splitting the reptiles into four subclasses based on the number and position of *temporal fenestrae*, openings in the sides of the skull behind the eyes. This classification was initiated by Henry Fairfield Osborn and elaborated an made popular by Romer's classic *Vertebrate Paleontology*. Those four subclasses were:

- Anapsida – no fenestrae - cotylosaurs and Chelonia (turtles and relatives)
- Synapsida – one low fenestra - pelycosaurs and therapsids (the 'mammal-like reptiles')
- Euryapsida – one high fenestra (above the postorbital and squamosal) - protorosaurs (small, early lizard-like reptiles) and diverse marine reptiles like plesiosaurs and ichthyosaurs, the latter called Parapsida in Osborn's work.
- Diapsida – two fenestrae - most reptiles, including lizards, snakes, crocodilians, dinosaurs and pterosaurs

The composition of Euryapsida was uncertain. Ichthyosaurs were at times considered to have arisen independently of the other euryapsids, and given the older name Parapsida. Parapsida was later discarded as a group for the most part (ichthyosaurs being classified as *incertae sedis* or with Euryapsida). This schema remained more or less universal for non-specialist work throughout the 20th century, and has only been challenged with the rising popularity of phylogenetic nomenclature.

Phylogenetics and modern definition

By the 21st century, most vertebrate paleontologists had adopted phylogenetic taxonomy, in which all groups are defined in such a way as to be monophyletic; that is, groups include all descendants of a particular ancestor. The reptiles as historically defined would be paraphyletic, since they exclude both birds and mammals, although these also evolved from the original reptile. Colin Tudge wrote:

Mammals are a clade, and therefore the cladists are happy to acknowledge the traditional taxon Mammalia; and birds, too, are a clade, universally ascribed to the formal taxon Aves. Mammalia and Aves are, in fact, subclades within the grand clade of the Amniota. But the traditional class Reptilia is not a clade. It is just a section of the clade Amniota: the section that is left after the Mammalia and Aves have been hived off. It cannot be defined by synapomorphies, as is the proper way. It is instead defined by a combination of the features it has and the features it lacks: reptiles are the amniotes that lack fur or feathers. At best, the cladists suggest, we could say that the traditional Reptilia are 'non-avian, non-mammalian amniotes'.

Despite the early proposals for a monophyletic Sauropsida, that term was never adopted widely or, when it was, applied consistently. When Sauropsida was used, it often had the same content or even the same definition as Reptilia. Reptilia was first defined as a clade in 1988 by Gauthier, as a monophyletic node-based crown group containing turtles, lizards and snakes, crocodilians, and birds, their common ancestor and all its descendants. A variety of other definitions were proposed by other scientists in the years following Gauthier's paper. The first which attempted to adhere to the standards of the PhyloCode was published by Modesto and Anderson in 2004. They reviewed the many previous definitions, and proposed a modified definition which they intended to retain most traditional content of the group while keeping it stable and monophyletic. They defined Reptilia as all amniotes closer to *Lacerta agilis* and *Crocodylus niloticus* than to *Homo sapiens*. This stem-based definition is equivalent to that of Sauropsida, which Modesto and Anderson synonymized with Reptilia, since the latter is more well known and more frequently used, despite their definition including birds.

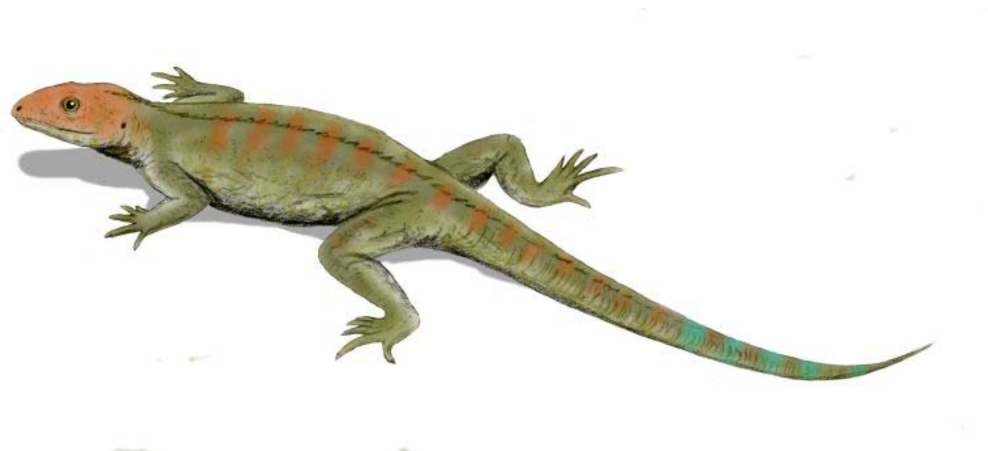
Taxonomy

Classification to order level, after Benton, 2004.

Series Amniota
Class Synapsida
Order Pelycosauria*
Order Therapsida
Class Mammalia
Class Sauropsida
Subclass Anapsida
Order Testudines (turtles)
A series of unassigned anapsid families, corresponding to Captorhinida, Mesosauria and Procolophonomorpha
Subclass Diapsida
Order Araeoscelidia
Order Younginiformes
Infraclass Ichthyosauria
Infraclass Lepidosauromorpha
Superorder Sauropterygia
Order Placodontia
Order Nothosauroidea
Order Plesiosauria
Superorder Lepidosauria
Order Sphenodontia (tuatara)
Order Squamata (lizards & snakes)
Infraclass Archosauromorpha
Order Prolacertiformes
Division Archosauria
Subdivision Crurotarsi
Superorder Crocodylomorpha
Order Crocodilia
Order Phytosauria
Order Rauisuchia
Order Rhynchosauria
Subdivision Avemetatarsalia
Infradivision Ornithodira
Order Pterosauria
Superorder Dinosauria
Order Saurischia
Class Aves
Order Ornithischia

Evolutionary history

Rise of the reptiles



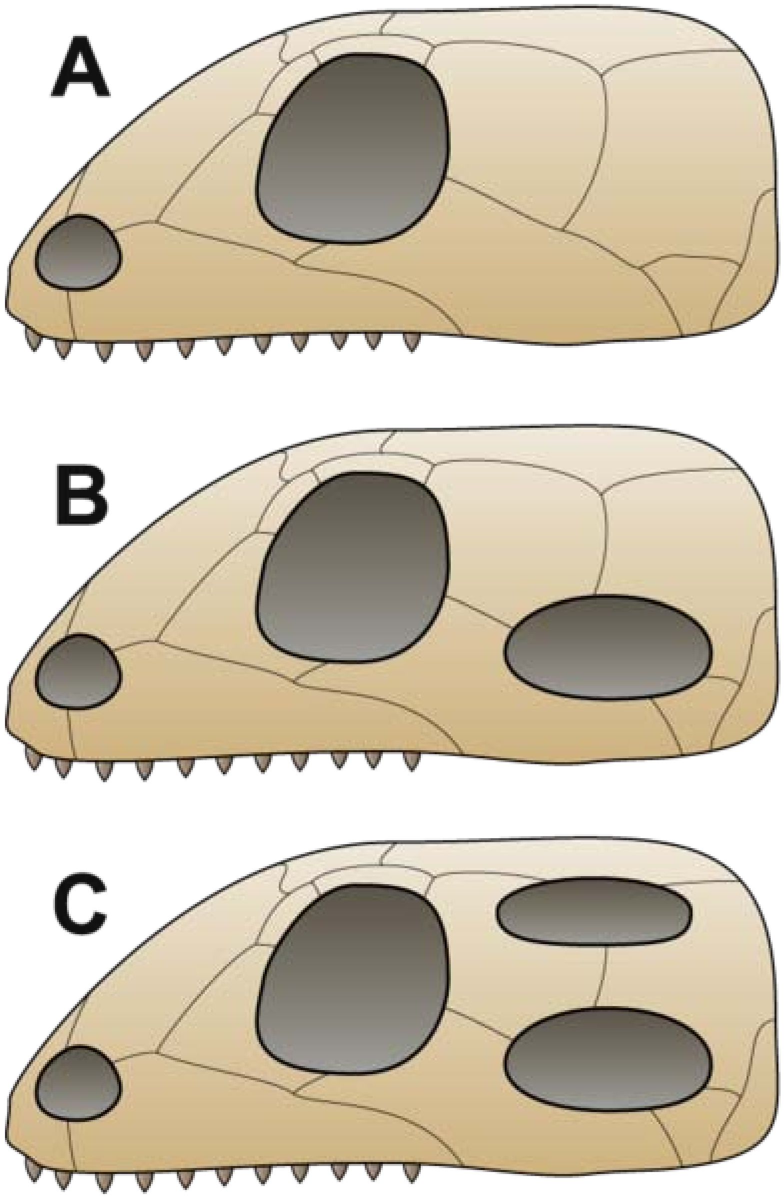
A early reptile *Hylonomus*

Mesozoic scene showing typical reptilian megafauna: the dinosaurs *Europasaurus holgeri* and *Iguanodon*, and the early bird *Archaeopteryx* perched on the foreground tree stump.

Megalania was a giant, carnivorous goanna that might have grown to as long as 7 metres, and weighed up to 1,940 kilograms (Molnar, 2004).

The origin of the reptiles lies about 320–310 million years ago, in the steaming swamps of the late Carboniferous period, when the first reptiles evolved from advanced reptiliomorph labyrinthodonts. The oldest known animal that may have been an amniote, i.e. a primitive reptile rather than an advanced amphibian is *Casineria*. A series of footprints from the fossil strata of Nova Scotia, dated to 315 million years show typical reptilian toes and imprints of scales. The tracks are attributed to *Hylonomus*, the oldest unquestionable reptile known. It was a small, lizard-like animal, about 20 to 30 cm (8–12 in) long, with numerous sharp teeth indicating an insectivorous diet. Other examples include *Westlothiana* (for the moment considered a reptiliomorph amphibian rather than a true amniote) and *Paleothyris*, both of similar build and presumably similar habit. One of the best known early reptiles is *Mesosaurus*, a genus from the early Permian that had returned to water, feeding on fish. The earliest reptiles were largely overshadowed by bigger labyrinthodont amphibians such as *Cochleosaurus*, and remained a small, inconspicuous part of the fauna until after the small ice age at the end of the Carboniferous.

Anapsids, synapsids, diapsids and sauropsids



A = Anapsid, B = Synapsid, C = Diapsid

The first reptiles were anapsids, having a solid skull with holes for only nose, eyes, spinal cord, etc. Very soon after the first reptiles appeared, they split into two branches. One branch, Synapsida (including both "mammal-like reptiles" and modern, extant mammals such as humans), had one opening in the skull roof behind each eye; the other branch, Diapsida, possessed a hole in their skulls behind each eye, along with a second hole located higher on the skull. The function of the holes in both groups was to lighten the skull and give room for the jaw muscles to move, allowing for a more powerful bite. Diapsids and later anapsids are classed as the "true reptiles", Sauropsida.

Turtles have been traditionally believed to be surviving anapsids, on the basis of their skull structure. The rationale for this classification was disputed, with some arguing that turtles are diapsids that reverted to this primitive state in order to improve their armor. Later morphological phylogenetic studies with this in mind placed turtles firmly within Diapsida. All molecular studies have strongly upheld the placement of turtles within diapsids, most commonly as a sister group to extant archosaurs.

Permian reptiles

With the close of the Carboniferous, reptiles became the dominant tetrapod fauna. While the terrestrial reptiliomorph labyrinthodonts still existed, the synapsids evolved the first truly terrestrial megafauna (giant animals) in the form of pelycosaurs such as *Edaphosaurus* and the carnivorous *Dimetrodon*. In the mid-Permian period the climate turned dryer, resulting in a change of fauna: The primitive pelycosaurs were replaced by the more advanced therapsids.

The anapsid reptiles, whose massive skull roofs had no postorbital holes, continued and flourished throughout the Permian. The pareiasaurs reached giant proportions in the late Permian, eventually disappearing at the close of the period (the turtles being possible survivors).

Early in the period, the diapsid reptiles split into two main lineages, the archosaurs (forefathers of crocodiles and dinosaurs) and the lepidosaurs (predecessors of modern snakes, lizards, and tuataras). Both groups remained lizard-like and relatively small and inconspicuous during the Permian.

The Mesozoic era, the "Age of Reptiles"

The close of the Permian saw the greatest mass extinction known. Most of the earlier anapsid/synapsid megafauna disappeared, being replaced by the archosauromorph diapsids. The archosaurs were characterized by elongated hind legs and an erect pose, the early forms looking somewhat like long-legged crocodiles. The archosaurs became the dominant group during the Triassic period, developing into the well-known dinosaurs and pterosaurs, as well as crocodiles and phytosaurs. Some of the dinosaurs developed into the largest land animals ever to have lived, making the Mesozoic era popularly known as the "Age of Reptiles". The dinosaurs also developed smaller forms, including the feather-bearing smaller theropods. In the mid-Jurassic period, these gave rise to the first birds.

The lepidosauromorph diapsids may have been ancestral to the sea reptiles. These reptiles developed into the sauropterygians in the early Triassic and the ichthyosaurs during the Middle Triassic. The mosasaurs also evolved in the Mesozoic era, emerging during the Cretaceous period.

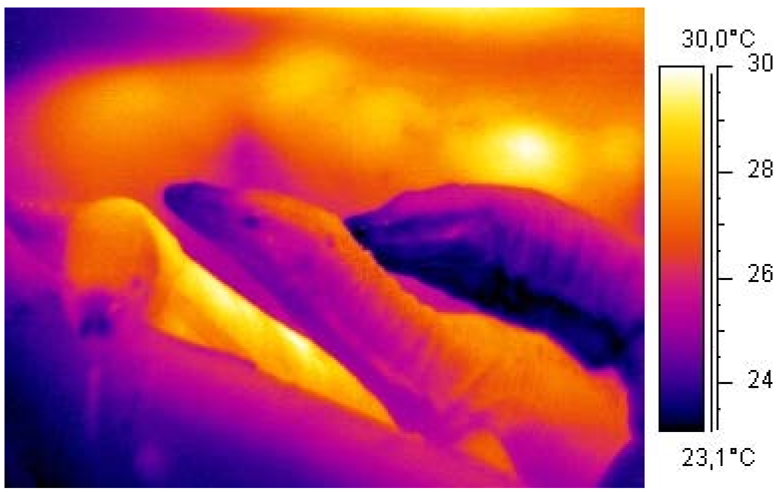
The therapsids came under increasing pressure from the dinosaurs in the early Mesozoic and developed into increasingly smaller and more nocturnal forms, the first mammals being the only survivors of the line by the late Jurassic.

Demise of the dinosaurs

The close of the Cretaceous period saw the demise of the Mesozoic era reptilian megafauna. Of the large marine reptiles, only sea turtles are left, and, of the dinosaurs, only the small feathered theropods survived in the form of birds. The end of the "Age of Reptiles" led into the "Age of Mammals". Despite the change in phrasing, reptile diversification continued throughout the Cenozoic, with squamates undergoing a greater radiation than they did in the Mesozoic. Today squamates make up the majority of extant reptiles today (over 90%). There are approximately 8,700 extant species of reptiles, compared with 5,400 species of mammals.

Systems

Circulation

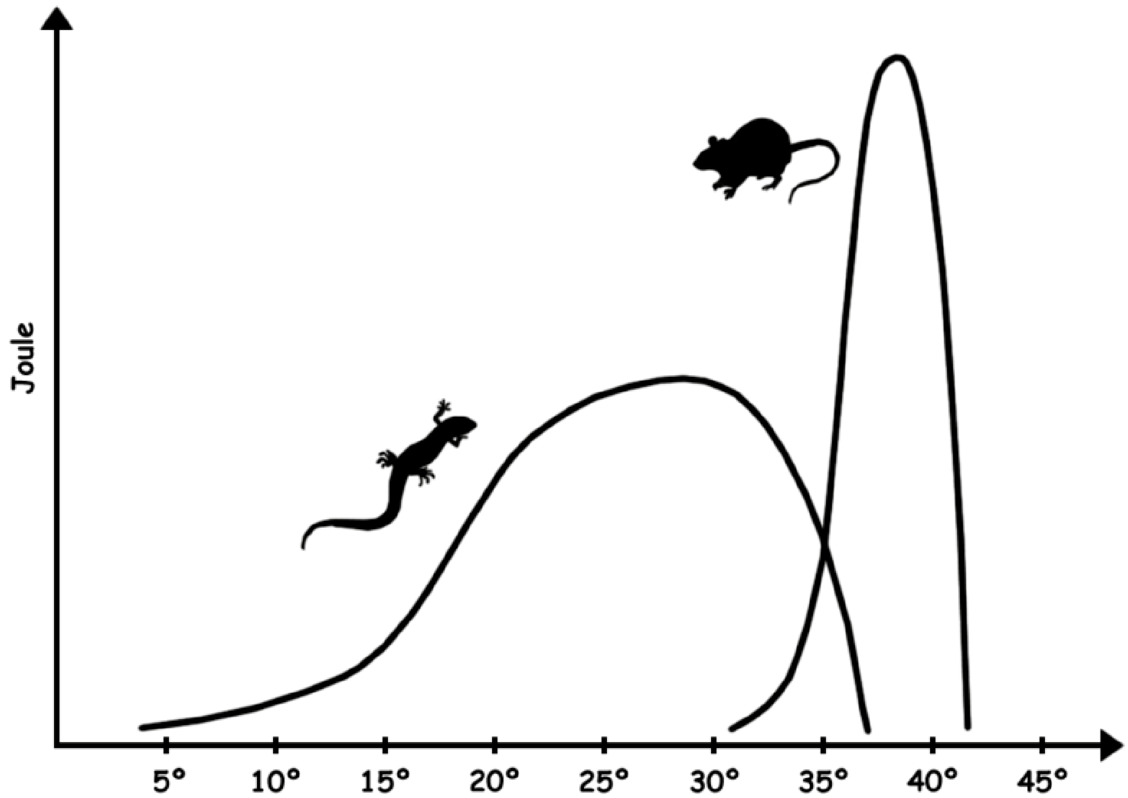


Thermographic image of a monitor lizard

Most reptiles have a three-chambered heart consisting of two atria, one variably partitioned ventricle, and two aortas that lead to the systemic circulation. The degree of mixing of oxygenated and deoxygenated blood in the three-chambered heart varies depending on the species and physiological state. Under different conditions, deoxygenated blood can be shunted back to the body or oxygenated blood can be shunted back to the lungs. This variation in blood flow has been hypothesized to allow more effective thermoregulation and longer diving times for aquatic species, but has not been shown to be a fitness advantage.

There are some exceptions to the general physiology. For instance, crocodilians have an anatomically four-chambered heart, but also have two systemic aortas and are therefore capable of bypassing only their pulmonary circulation. Also, some snake and lizard species (e.g., pythons and monitor lizards) have three-chambered hearts that become functionally four-chambered hearts during contraction. This is made possible by a muscular ridge that subdivides the ventricle during ventricular diastole and completely divides it during ventricular systole. Because of this ridge, some of these squamates are capable of producing ventricular pressure differentials that are equivalent to those seen in mammalian and avian hearts.

Metabolism



Sustained energy output (Joule) of a typical reptile versus a similar size mammal as a function of core body temperature. The mammal has a much higher peak output, but can only function over a very narrow range of body temperatures.

All reptiles exhibit some form of cold-bloodedness (i.e. some mix of poikilothermy, ectothermy, and bradymetabolism). This means that most reptiles have limited physiological means of keeping the body temperature constant, and often rely on external sources of heat. Due to a less stable core temperature than birds and mammals, reptilian biochemistry requires enzymes capable of maintaining efficiency over a greater range of temperatures than warm-blooded animals. The optimum body temperature range varies with species, but is typically below that of warm-blooded animals, in the 24°–35°C range for many lizards, while extreme heat adapted species like the American desert iguana *Dipsosaurus dorsalis* can have optimal physiological temperatures in the mammalian range, between 35 and 40°C. While the optimum temperature is often encountered when the animal is active, the low basal metabolism makes body temperature drop rapidly when the animal is inactive.

Like in all animals, reptilian muscle action produces heat. In large reptiles, like leatherback turtles, the low surface to volume ratio allows this metabolically produced heat to keep the animals warmer than their environment, despite not having a warm-blooded metabolism. This form of homeothermy is called gigantothermy, and has been suggested as having been common in large dinosaurs and other extinct large-bodied reptiles.

The benefits of a low resting metabolism is that it requires far less fuel to sustain bodily functions. By using temperature variations in their surroundings or by remaining cold when they do not need to move, reptiles can save considerable amounts of energy compared to endotherm animals of the same size. A crocodile need from a fifth to a tenth of the food necessary for a lion of the same weight, and can live half a year without eating. Lower food requirements and adaptive metabolisms allow reptiles to dominate the animal life in regions where net calorie production is too low to sustain large-bodied mammals and birds.

It is generally assumed that reptiles are unable to produce the sustained high energy output necessary for long distance chases or flying. Higher energetic capacity might have been responsible for the evolution of warm-bloodedness in birds and mammals. However, investigation of correlations between active capacity and thermophysiology show a weak relationship. Most extant reptiles are carnivores with a sit-and-wait feeding strategy, and whether reptiles are cold blooded due to their ecology, or if their metabolism is a result of their ecology is not clear. Energetic studies on some reptiles have shown active capacities equal to, or greater than similar sized warm-blooded animals.

Respiration

Reptilian lungs

All reptiles breathe using lungs. Aquatic turtles have developed more permeable skin, and some species have modified their cloaca to increase the area for gas exchange. Even with these adaptations, breathing is never fully accomplished without lungs. Lung ventilation is accomplished differently in each main reptile group. In squamates, the lungs are ventilated almost exclusively by the axial musculature. This is also the same musculature that is used during locomotion. Because of this constraint, most squamates are forced to hold their breath during intense runs. Some, however, have found a way around it. Varanids, and a few other lizard species, employ buccal pumping as a complement to their normal "axial breathing." This allows the animals to completely fill their lungs during intense locomotion, and thus remain aerobically active for a long time. Tegu lizards are known to possess a proto-diaphragm, which separates the pulmonary cavity from the visceral cavity. While not actually capable of movement, it does allow for greater lung inflation, by taking the weight of the viscera off the lungs. Crocodilians actually have a muscular diaphragm that is analogous to the mammalian diaphragm. The difference is that the muscles for the crocodilian diaphragm pull the pubis (part of the pelvis, which is movable in crocodilians) back, which brings the liver down, thus freeing space for the lungs to expand. This type of diaphragmatic setup has been referred to as the "hepatic piston."

Turtles and tortoises

Red-eared slider taking a gulp of air

How turtles and tortoises breathe has been the subject of much study. To date, only a few species have been studied thoroughly enough to get an idea of how turtles do it. The results indicate that turtles and tortoises have found a variety of solutions to this problem.

The difficulty is that most turtle shells are rigid and do not allow for the type of expansion and contraction that other amniotes use to ventilate their lungs. Some turtles such as the Indian flapshell (*Lissemys punctata*) have a sheet of muscle that envelops the lungs. When it contracts, the turtle can exhale. When at rest, the turtle can retract the limbs into the body cavity and force air out of the lungs. When the turtle protracts its limbs, the pressure inside the lungs is reduced, and the turtle can suck air in. Turtle lungs are attached to the inside of the top of the shell (carapace), with the bottom of the lungs attached (via connective tissue) to the rest of the viscera. By using a series of special muscles (roughly equivalent to a diaphragm), turtles are capable of pushing their viscera up and down, resulting in effective respiration, since many of these muscles have attachment points in conjunction with their forelimbs (indeed, many of the muscles expand into the limb pockets during contraction).

Breathing during locomotion has been studied in three species, and they show different patterns. Adult female green sea turtles do not breathe as they crutch along their nesting beaches. They hold their breath during terrestrial locomotion and breathe in bouts as they rest. North American box turtles breathe continuously during locomotion, and the ventilation cycle is not coordinated with the limb movements. This is because they use their abdominal muscles to breathe during locomotion. The last species to have been studied is the red-eared slider, which also breathes during locomotion, but takes smaller breaths during locomotion than during small pauses between locomotor bouts, indicating that there may be mechanical interference between the limb movements and the breathing apparatus. Box turtles have also been observed to breathe while completely sealed up inside their shells.

Palate

Most reptiles lack a secondary palate, meaning that they must hold their breath while swallowing. Crocodilians have evolved a bony secondary palate that allows them to continue breathing while remaining submerged (and protect their brains against damage by struggling prey). Skinks (family Scincidae) also have evolved a bony secondary palate, to varying degrees. Snakes took a different approach and extended their trachea instead. Their tracheal extension sticks out like a fleshy straw, and allows these animals to swallow large prey without suffering from asphyxiation.

Skin

The foot of a skink, showing squamate reptiles iconic scales

Reptilian skin is covered in a horny epidermis, making it watertight and enabling reptiles to live on dry land, in contrast to amphibians. Compared to mammalian skin, that of reptiles is rather thin and lacks the thick dermal layer that produces leather in mammals. Exposed parts of reptiles are protected by scales or scutes, sometimes with a bony base, forming armor. In lepidosaurians such as lizards and snakes, the whole skin is covered in overlapping epidermal scales. Such scales were once thought to be typical of the class Reptilia as a whole, but are now known to occur only in lepidosaurians. The scales found in turtles and crocodiles are of dermal, rather than epidermal, origin and are properly termed scutes. In turtles, the body is hidden inside a hard shell composed of fused scutes.

Lacking a thick dermis, reptilian leather is not as strong as mammalian leather. It is used in leather-wares for decorative purposes for shoes, belts and handbags, particularly crocodile skin. Due to reptiles lacking feathers or fur, reptiles are used as pets by people with allergies.

Excretion

Excretion is performed mainly by two small kidneys. In diapsids, uric acid is the main nitrogenous waste product; turtles, like mammals, excrete mainly urea. Unlike the kidneys of mammals and birds, reptile kidneys are unable to produce liquid urine more concentrated than their body fluid. This is because they lack a specialized structure called a loop of Henle, which is present in the nephrons of birds and mammals,. Because of this, many reptiles use the colon to aid in the reabsorption of water. Some are also able to take up water stored in the bladder. Excess salts are also excreted by nasal and lingual salt glands in some reptiles.

Digestion

Watersnake *Malpolon monspessulanus* eating a lizard. Most reptiles are carnivorous, and many primarily eat other reptiles.

Most reptiles are carnivorous and have rather simple and comparatively short digestive tracts, meat being fairly simple to break down and digest. Digestion is slower than in mammals, reflecting their lower resting metabolism and their inability to divide and masticate their food. Their poikilotherm metabolism has very low energy requirements, allowing large reptiles like crocodiles and the large constrictors to live from a single large meal for months, digesting it slowly.

While modern reptiles are predominately carnivorous, during the early history of reptiles several groups produced some herbivorous megafauna: in the Paleozoic the pareiasaurs and the synapsid dicynodonts, and in the Mesozoic several lines of dinosaurs. Today the turtles are the only predominantly herbivorous reptile group, but several lines of agamas and iguanas have evolved to live wholly or partly on plants.

Herbivorous reptiles face the same problems of mastication as herbivorous mammals but, lacking the complex teeth of mammals, many species swallow rocks and pebbles (so called gastroliths) to aid in digestion: The rocks are washed around in the stomach, helping to grind up plant matter. Fossil gastroliths have been found associated with sauropods. Sea turtles, crocodiles, and marine iguanas also use gastroliths as ballast, helping them to dive.

Nerves

The reptilian nervous system contains the same basic part of the amphibian brain, but the reptile cerebrum and cerebellum are slightly larger. Most typical sense organs are well developed with certain exceptions, most notably the snake's lack of external ears (middle and inner ears are present). There are twelve pairs of cranial nerves. Due to their short cochlea, reptiles use electrical tuning to expand their range of audible frequencies.

Reptiles are generally considered less intelligent than mammals and birds. The size of their brain relative to their body is much less than that of mammals, the encephalization quotient being about one tenth of that of mammals. Though larger reptiles show more complex brain developement. Larger lizards like the monitors are known to exhibit complex behavior, including cooperation. Crocodiles have relatively larger brains and show a fairly complex social structure. The Komodo dragon is even known to engage in play.

Vision

Most reptiles are diurnal animals. The vision is typically adapted to daylight conditions, with color vision and more advanced visual depth perception than in amphibians and most mammals. In some species, such as blind snakes, vision is reduced. Some snakes have extra sets of visual organs (in the loosest sense of the word) in the form of pits sensitive to infrared radiation (heat). Such heat-sensitive pits are particularly well developed in the pit vipers, but are also found in boas and pythons. These pits allow the snakes to sense the body heat of birds and mammals, enabling pit vipers to hunt rodents in the dark.

Reproduction

Most reptiles reproduce sexually such as this *Trachylepis maculilabris* skink

Reptiles have amniotic eggs with hard or leathery shells, requiring internal fertilization.

Most reptiles reproduce sexually, though some are capable of asexual reproduction. All reproductive activity occurs through the cloaca, the single exit/entrance at the base of the tail where waste is also eliminated. Most reptiles have copulatory organs, which are usually retracted or inverted and stored inside the body. In turtles and crocodilians, the male has a single median penis, while squamates, including snakes and lizards, possess a pair of hemipenes. Tuataras, however, lack copulatory organs, and so the male and female simply press their cloacas together as the male excretes sperm.

Most reptiles lay amniotic eggs covered with leathery or calcareous shells. An amnion, chorion, and allantois are present during embryonic life. There are no larval stages of development. Viviparity and ovoviviparity have evolved only in squamates, and many species, including all boas and most vipers, utilize this mode of reproduction. The degree of viviparity varies: some species simply retain the eggs until just before hatching, others provide maternal nourishment to supplement the yolk, and yet others lack any yolk and provide all nutrients via a structure similar to the mammalian placenta.

Asexual reproduction has been identified in squamates in six families of lizards and one snake. In some species of squamates, a population of females is able to produce a unisexual diploid clone of the mother. This form of asexual reproduction, called parthenogenesis, occurs in several species of gecko, and is particularly widespread in the teiids (especially *Aspidocelis*) and lacertids (*Lacerta*). In captivity, Komodo dragons (Varanidae) have reproduced by parthenogenesis.

Parthenogenetic species are suspected to occur among chameleons, agamids, xantusiids, and typhlopids.

Some reptiles exhibit temperature-dependent sex determination (TDSD), in which the incubation temperature determines whether a particular egg hatches as male or female. TDSD is most common in turtles and crocodiles, but also occurs in lizards and tuataras. To date, there has been no confirmation of whether TDSD occurs in snakes.

Defense mechanisms

Many small reptiles such as snakes and lizards which live on the ground or in the water are vulnerable to being preyed on by all kinds of carnivorous animals. Thus avoidance is the most common form of defense in reptiles. At the first sign of danger, most snakes and lizards crawl away into the undergrowth, and turtles and crocodiles will plunge into water and sink out of sight.

A camouflaged *Phelsuma deubia* on a palm frond

Reptiles may also avoid confrontation through camouflage. Using a variety of grays, greens, and browns, these animals can blend remarkably well into the background of their natural environment.

If the danger arises so suddenly that flight may be harmful, then crocodiles, turtles, some lizards, and some snakes hiss loudly when confronted by an enemy. Rattlesnakes rapidly vibrate the tip of the tail, which is composed of a series of nested, hollow beads.

If all this does not deter an enemy, different species will adopt different defensive tactics.

Snakes use a complicated set of behaviors when attacked. Some will first elevate their head and spread out the skin of their neck in an effort to look bigger and more threatening. Failure of this may lead to other measures practiced particularly by cobras, vipers, and closely related species, who use venom to attack. The venom is modified saliva, delivered through fangs from a venom gland. Some non-venomous snakes, such as the corn snake, play dead when in danger.

When a crocodile is concerned about its safety, it will gape to expose the teeth and yellow tongue. If this doesn't work, the crocodile gets a little more agitated and typically begins to make hissing sounds. After this, the crocodile will start to change its posture dramatically to make itself look more intimidating. The body is inflated to increase apparent size. If absolutely necessary it may decide to attack an enemy.

A White-headed dwarf gecko with shed tail

Some species try to bite immediately. Some will use their heads as sledgehammers and literally smash an opponent, some will rush or swim toward the threat from a distance, even chasing them onto land or galloping after them.

Geckos, skinks, and other lizards that are captured by the tail will shed part of the tail structure through a process called autotomy and thus be able to flee. The detached tail will continue to wiggle, creating a deceptive sense of continued struggle and distracting the predator's attention from the fleeing prey animal. The animal can partially regenerate its tail over a period of weeks. The new section will contain cartilage rather than bone, and the skin may be distinctly discolored compared to the rest of the body. The tails are often a separate and dramatically more vivid color then the rest of the body, as to attract potential predators to strike for the tail first.

Chapter- 2

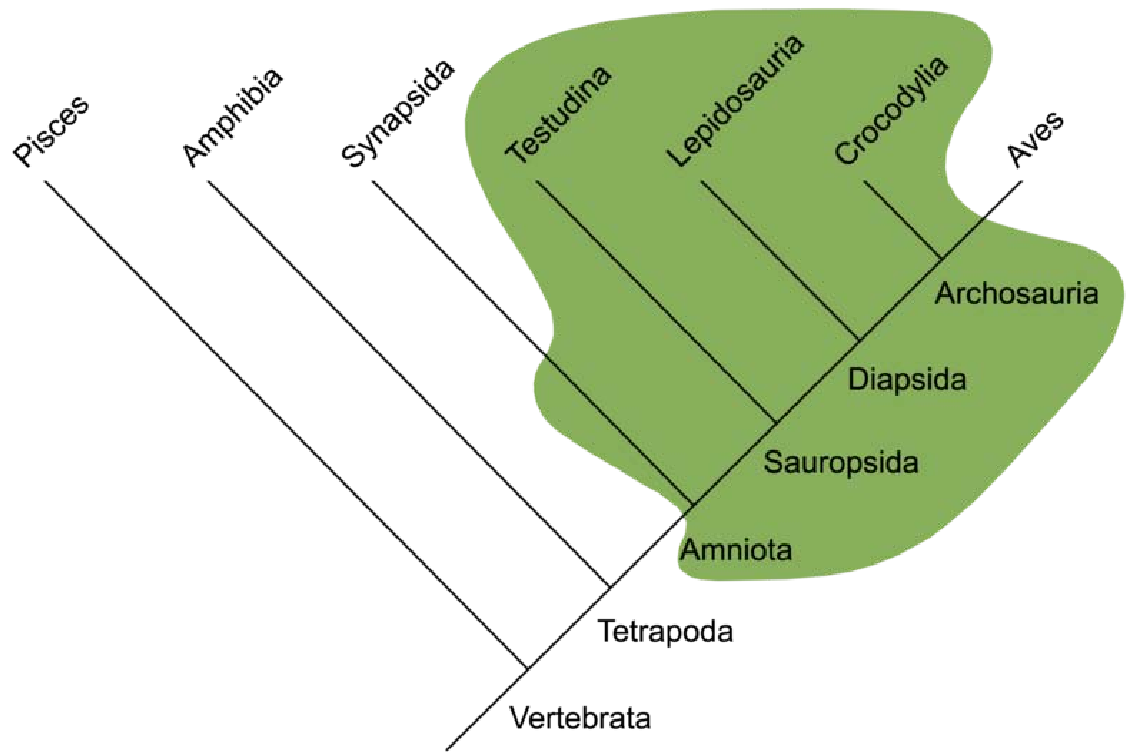
Evolution of Reptiles

A fossil of a Casineria. The earliest evidence of amniotes, although an amphibian, it laid eggs on land as reptiles do.

Reptiles first arose about 310-320 million years ago in the Carboniferous period. Reptiles are defined as animals that have scales, lay land based hard shelled eggs, and possessing cold-blooded metabolisms. Today reptiles generally rank low in most ecological food chains, containing very few apex predators, but many examples of apex reptiles have existed in the past. Although reptiles have lower specie variation than in the past, they have an extremely diverse evolutionary history that has led to biological successes such as dinosaurs, mammals, and birds.

First reptiles

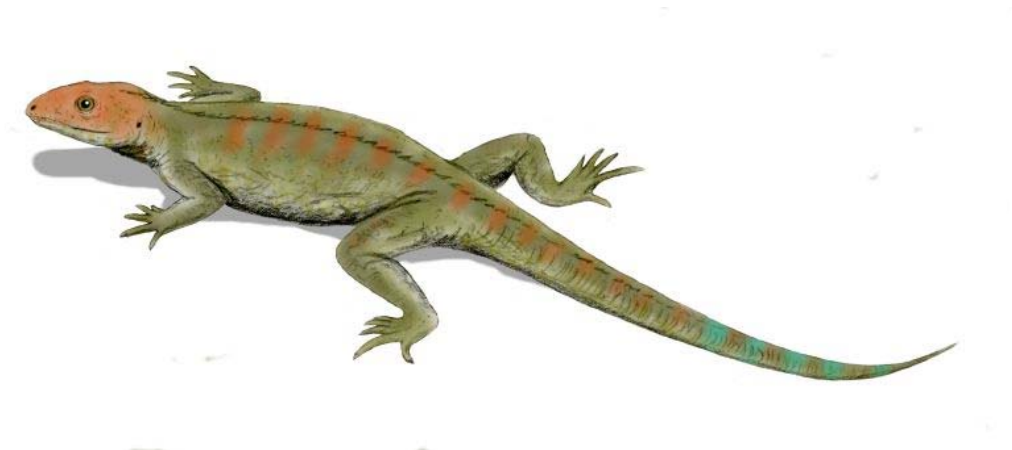
Rise from water



Reptiles (green field) are a paraphyletic group comprising all non-avian and non-mammalian amniotes.

Reptiles first arose from amphibians in the swamps of the late Carboniferous. Increasing evolutionary pressure and the vast untouched niches of the land powered the evolutionary changes in amphibians to gradually become more and more land based. Environmental selection propelled the development of certain traits, such as a stronger skeletal structure, muscles, and more protective coating (scales) became more favorable, the basic foundation of reptiles were founded. The evolution of lungs and legs are the main transitional steps towards reptiles, but the development of hard-shelled external eggs replacing the amphibious water bound eggs is the defining feature of the class reptilia (with the exception of certain squamates) and is what allowed amphibians to fully leave water. Another major difference from amphibians is the increased brain size, more specifically, the enlarged cerebrum and cerebellum. Although there brain size is small when compared to mammals and birds, these enhancements prove vital in hunting strategies of reptiles. The increased size of these two regions of the brain allowed for improved motor skills and an increase in sensory development.

Early reptiles

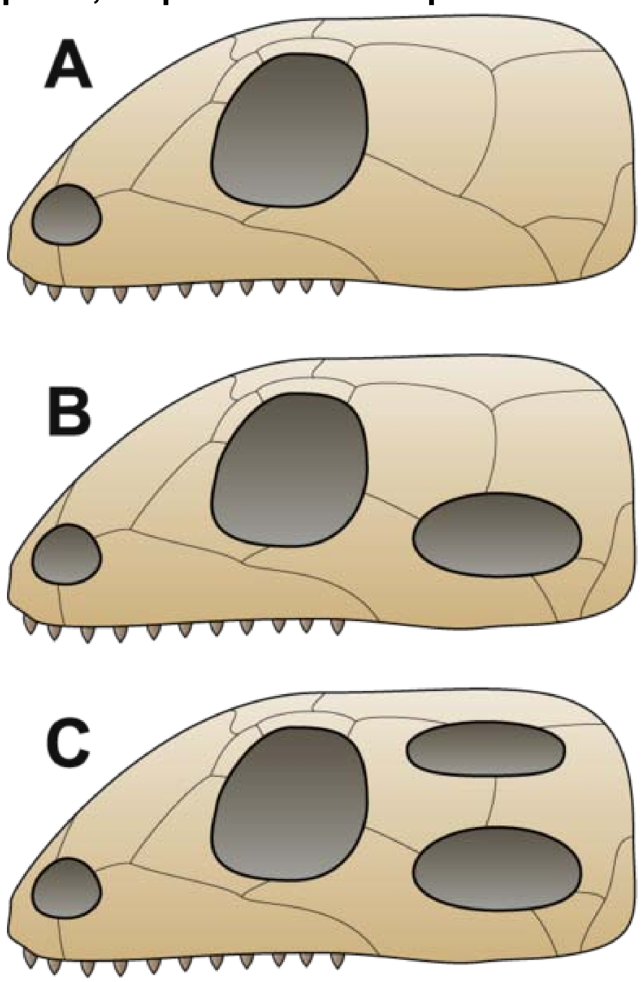


An early reptile *Hylonomus*

Mesozoic scene showing typical reptilian megafauna: the dinosaurs *Europasaurus holgeri* and *Iguanodon*, and the early bird *Archaeopteryx* perched on the foreground tree stump.

The origin of the reptiles lies about 320–310 million years ago, in the steaming swamps of the late Carboniferous period, when the first reptiles evolved from advanced reptiliomorph labyrinthodonts. The oldest known animal that may have been an amniote, i.e. a primitive reptile rather than an advanced amphibian is *Casineria*. A series of footprints from the fossil strata of Nova Scotia, dated to 315 million years show typical reptilian toes and imprints of scales. The tracks are attributed to *Hylonomus*, the oldest unquestionable reptile known. It was a small, lizard-like animal, about 20 to 30 cm (8–12 in) long, with numerous sharp teeth indicating an insectivorous diet. Other examples include *Westlothiana* (for the moment considered a reptiliomorph amphibian rather than a true amniote) and *Paleothyris*, both of similar build and presumably similar habit. One of the best known early reptiles is *Mesosaurus*, a genus from the early Permian that had returned to water, feeding on fish. The earliest reptiles were largely overshadowed by bigger labyrinthodont amphibians such as *Cochleosaurus*, and remained a small, inconspicuous part of the fauna until after the small ice age at the end of the Carboniferous.

Anapsids, synapsids, diapsids and sauropsids



A = Anapsid, B = Synapsid, C = Diapsid

The first reptiles were anapsids, having a solid skull with holes for only nose, eyes, spinal cord, etc. Very soon after the first reptiles appeared, they split into two branches. One branch, Synapsida (including both "mammal-like reptiles" and modern, extant mammals), had one opening in the skull roof behind each eye; the other branch, Diapsida, possessed a hole in their skulls behind each eye, along with a second hole located higher on the skull. The function of the holes in both groups was to lighten the skull and give room for the jaw muscles to move, allowing for a more powerful bite. Diapsids and later anapsids are classed as the "true reptiles", Sauropsida.

Turtles have been traditionally believed to be surviving anapsids, on the basis of their skull structure. The rationale for this classification was disputed, with some arguing that turtles are diapsids that reverted to this primitive state in order to improve their armor. Later morphological phylogenetic studies with this in mind placed turtles firmly within Diapsida. All molecular studies have strongly upheld the placement of turtles within diapsids, most commonly as a sister group to extant archosaurs.

Mammalian evolution

A basic cladogram of the origin of modern mammals from their closest reptilian relatives.

The main points to the transition from reptile to mammal was the evolution from scales to hair or fur, the evolution of warm-bloodedness, the loss of external eggs (except for in monotremes who have retained this trait), and the evolution mammary glands (the most defining trait in mammals that allow them to produce milk for offspring). The evolution of mammals 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 modern 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.

Rise of dinosaurs

Permian reptiles

With the close of the Carboniferous, reptiles became the dominant tetrapod fauna. While the terrestrial reptiliomorph labyrinthodonts still existed, the synapsids evolved the first truly terrestrial megafauna (giant animals) in the form of pelycosaurs such as *Edaphosaurus* and the carnivorous *Dimetrodon*. In the mid-Permian period the climate turned dryer, resulting in a change of fauna: The primitive pelycosaurs were replaced by the more advanced therapsids.

The anapsid reptiles, whose massive skull roofs had no postorbital holes, continued and flourished throughout the Permian. The pareiasaurs reached giant proportions in the late

Permian, eventually disappearing at the close of the period (the turtles being possible survivors).

Early in the period, the diapsid reptiles split into two main lineages, the archosaurs (forefathers of crocodiles and dinosaurs) and the lepidosaurs (predecessors of modern snakes, lizards, and tuataras). Both groups remained lizard-like and relatively small and inconspicuous during the Permian.

The Mesozoic era, the "Age of Reptiles"

The close of the Permian saw the greatest mass extinction known. Most of the earlier anapsid/synapsid megafauna disappeared, being replaced by the archosauromorph diapsids. The archosaurs were characterized by elongated hind legs and an erect pose, the early forms looking somewhat like long-legged crocodiles. The archosaurs became the dominant group during the Triassic period, developing into the well-known dinosaurs and pterosaurs, as well as crocodiles and phytosaurs. Some of the dinosaurs developed into the largest land animals ever to have lived, making the Mesozoic era popularly known as the "Age of Reptiles". The dinosaurs also developed smaller forms, including the feather-bearing smaller theropods. In the mid-Jurassic period, these gave rise to the first birds.

The lepidosauromorph diapsids may have been ancestral to the sea reptiles. These reptiles developed into the sauropterygians in the early Triassic and the ichthyosaurs during the Middle Triassic. The mosasaurs also evolved in the Mesozoic era, emerging during the Cretaceous period.

The therapsids came under increasing pressure from the dinosaurs in the early Mesozoic and developed into increasingly smaller and more nocturnal forms, the first mammals being the only survivors of the line by the late Jurassic.

Bird evolution

An *Archaeopteryx* specimen in Berlin.

The main points to the transition from reptile to bird is the evolution from scales to feathers, the evolution of the beak (although independently evolved in other organisms), the hallofication of bones, development of flight, and warm-bloodedness.

The evolution of birds is thought to have begun in the Jurassic Period, with the earliest birds derived from theropod dinosaurs. Birds are categorized as a biological class, Aves. The earliest known species Aves is *Archaeopteryx lithographica*, from the Late Jurassic period, though 'Archaeopteryx is not commonly considered to have been a true bird, but a transitional species between Aves and Reptiles. Modern phylogenetics place birds in the dinosaur clade Theropoda. According to the current consensus, Aves and a sister group of the order Crocodilia, together are the sole living members of an unranked "reptile" clade, the Archosauria.

Demise of the dinosaurs

The close of the Cretaceous period saw the demise of the Mesozoic era reptilian megafauna. Along with massive amount of volcanic activity at the time, the meteor impact that created the K-T boundary is accepted as the main cause for this mass extinction event. Of the large marine reptiles, only sea turtles are left, and, of the dinosaurs, only the small feathered theropods survived in the form of birds. The end of the “Age of Reptiles” led into the “Age of Mammals”. Despite the change in phrasing, reptile diversification continued throughout the Cenozoic, with squamates undergoing a greater radiation than they did in the Mesozoic. Today squamates make up the majority of extant reptiles today (over 90%), filling many of the ecological niches left by the mammals who would take advantage of the niches left by the dinosaurs. There are approximately 8,700 extant species of reptiles, compared with 5,400 species of mammals.

Role reversal

After the Cretaceous-Tertiary extinction wiped out all of 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 era. Some reaching enormous sizes and almost as wide of a variation as the dinosaurs once did. Due to global climate changes such as a lowering in total oxygen levels and lower average temperatures, mammalian megafauna never quite reached the sky-scraper heights as did some sauropods. These evolutionary and climatic changes is what is responsible for all modern orders of mammals that are now on Earth, including humans.

The four orders of reptilia

Sphenodontia

Sphenodontians arose in the mid Triassic and only consist of one genus tuatara, which only includes two endangered species on New Zealand and some other minor surrounding islands. Their evolutionary history is filled with many species. Recent paleogenetic discoveries show that tuataras are prone to quick speciation.

Crocodilia

The first organisms that showed similar characteristics of Crocodilians would be the Crurotarsi who appeared during the early Triassic 250 million years ago. This quickly gave rise to the Eusuchia clade 220 million years ago which would eventually lead to the order of Crocodilians, first of which arose about 85 million years ago during the late cretaceous, originating from the Eusuchia clade. The earliest fossil evidence of eusuchians is of the species Isisfordia. Early species mainly feed on fish and vegetation. They were land-based, most having long legs (when compared to modern crocodiles) and many were bipeadal. As diversification increased, many apex predators arose, all of which is now extinct. Modern Crocodilia arose through specific evolutionary traits. The complete loss of bipedalism in trade for generally low quadrupedal stance for an easy and less noticeable entrance to bodies of water. The shape of the skull/jaw changed to allow further grasp along with up-ward pointing nostrils and eyes. Mimicry is evident, as the back of all crocodilia resemble some type floating log along with their general color scheme of brown and green to mimic moss or wood. There tail also took on a paddle shape to increase swimming speed. The only remaining groups to this order is the alligator, crocodile, caiman, and gharial.

Testudines

Testudines, or turtles, may have evolved from anaspidas, but their exact origin is unknown and heavily debated. Fossils date back to around 220 million years ago and share remarkably similar characteristics. These first turtles retain the same body plan as do all modern testudines and are mostly herbivorous. With some feeding exclusively on small marine organisms. The trade-mark shell is believed to have evolved from extensions from there backbone and widened ribs which fused together. This is supported by the fossil of Odontochelys semitestacea, which has an incomplete shell originating from the ribs and back bone. This species also had teeth with its beak, giving more support to it being a transitional fossil, although this claim is still controversial. This shell evolved to protect itself from predators, but also slows down the land based species by a great amount. This has caused many species to go extinct in recent times. Because of alien species out-competing the slow order for food and lack of ability to escape from humans, there are large amounts of endangered species in this order.

Squamata

The most recent order of reptiles, squamates are recognized by having a movable quadrate bone (giving them upper-jaw movement) and possessing horny scales. They originate from the early Jurassic and are made up of the three suborders Lacertilia, Serpentes, and Amphisbaenia. Although they are the most recent order, squamates contain more species than any of the other reptilian orders. Squamates are a monophyletic group that is a sister group to the Sphenodontia or tuataras. The squamates and tuatara together are a sister group to crocodiles and birds, the extant archosaurs. Although squamate fossils first appear in the early Jurassic, mitochondrial phylogenetics suggests that they evolved in the late Permian. Most evolutionary relationships within the squamates are not yet completely worked out, with the relationship of snakes to other groups being most problematic. From morphological data, Iguanid lizards have been thought to have diverged from other squamates very early, but recent molecular phylogenies, both from mitochondrial and nuclear DNA, do not support this early divergence. Because snakes have a faster molecular clock than other squamates, and there are few early snake and snake ancestor fossils, it is difficult to resolve the relationship between snakes and other squamate groups.

Chapter- 3

Lizard (Type of Reptile)

Lizards **Temporal range: 199–0 Ma** **Jurassic- Present**	

Central bearded dragon, *Pogona vitticeps*

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Superclass:	Tetrapoda
Class:	Reptilia
Order:	Squamata
Suborder:	**Lacertilia*** Günther, 1867

Lizards are a widespread group of squamate reptiles, with nearly 3800 species, ranging across all continents except Antarctica as well as most oceanic island chains. The group, traditionally recognized as the suborder **Lacertilia**, is defined as all extant members of the Lepidosauria (reptiles with overlapping scales), which are neither sphenodonts (i.e., *tuatara*) nor snakes. While the snakes are recognized as falling phylogenetically within the anguimorph lizards from which they evolved, the sphenodonts are the sister group to the squamates, the larger monophyletic group, which includes both the lizards and the snakes.

Lizards typically have limbs and external ears, while snakes lack both these characteristics. However, because they are defined negatively as excluding snakes, lizards have no unique distinguishing characteristic as a group. Lizards and snakes share a movable quadrate bone, distinguishing them from the sphenodonts, which have a more primitive and solid diapsid skull. Many lizards can detach their tails to escape from predators, an act called autotomy, but this trait is not shared by all lizards. Vision, including color vision, is particularly well developed in most lizards, and most communicate with body language or bright colors on their bodies as well as with pheromones.

The adult length of species within the suborder ranges from a few centimetres for some chameleons and geckos to nearly three metres (9 feet, 6 inches) in the case of the largest living varanid lizard, the Komodo Dragon. Some extinct varanids reached great size. The extinct aquatic mosasaurs reached 17 metres, and the giant monitor *Megalania prisca* is estimated to have reached perhaps seven metres.

Physiology

Feral Jackson's Chameleon from a population introduced to Hawaii in the 1970s

Sight is very important for most lizards, both for locating prey and for communication, and, as such, many lizards have highly acute color vision. Most lizards rely heavily on body language, using specific postures, gestures, and movements to define territory, resolve disputes, and entice mates. Some species of lizard also utilize bright colors, such as the iridescent patches on the belly of Sceloporus. These colors would be highly visible to predators, so are often hidden on the underside or between scales and only revealed when necessary.

The particular innovation in this respect is the dewlap, a brightly colored patch of skin on the throat, usually hidden between scales. When a display is needed, the lizards erect the hyoid bone of their throat, resulting in a large vertical flap of brightly colored skin beneath the head which can be then used for communication. Anoles are particularly famous for this display, with each species having specific colors, including patterns only visible under ultraviolet (UV) light, as lizards can often see UV.

Evolution and relationships

Fossil mosasaur *Prognathodon*, a varanoid

The retention of the basic 'reptilian' amniote body form by lizards makes it tempting to assume any similar animal, alive or extinct, is also a lizard. However, this is not the case, and lizards as squamates are part of a well-defined group.

The earliest amniotes were superficially lizard-like, but had solid, box-like skulls, with openings only for eyes, nostrils, termed the anapsid condition. Turtles retain this skull form. Early anapsids later gave rise to two new groups with additional holes in the skull to make room for and anchor larger jaw muscles. The Synapsids, with a single fenestra, gave rise to the superficially lizard-like Pelycosaurs, which include *Dimetrodon* and the Therapsids, including the Cynodonts, from which the modern mammals would evolve.

The Diapsids, possessing one temporal fenestra before the eye and one behind it, continued to diversify. One branch, the Archosaurs, retained the basic Diapsid skull, and gave rise to a bewildering array of animals, most famous being the crocodilians, the pterosaurs, the dinosaurs and their descendants, birds. The Ichthyosaurs and Plesiosaurs radiated from the same basal Diapsid group.

The smaller Lepidosaur branch, which would give rise to the lizards, began to reduce the skull bones, making the skull lighter and more flexible. The modern *Tuatara* retains the basic Lepidosaur skull, distinguishing it from true lizards in spite of superficial similarities. Squamates, including snakes and all true lizards, further lightened the skull by eliminating the lower margin of the lower skull opening.

Lizard diversification

Within the **Lacertilia** are found four generally recognized suborders, Iguania, Gekkota, Amphisbaenia and Autarchoglossa, with the "blind skinks" in the family Dibamidae having an uncertain position. While traditionally excluded from the lizards, the snakes are usually classified as a clade with a similar subordinal rank.

Iguania

Anoles mating, Gainesville, FL

The suborder Iguania, found in Africa, south Asia, Australia, the New World, and with iguanas colonizing the islands of the west Pacific, form the sister group to the remainder of the squamata. They are largely arboreal, and have primitively fleshy, non-prehensile tongues ,some even have scales, but this condition is obviously highly modified in the chameleons. This clade includes the following families:

- Family Agamidae – Agamid Lizards, Old World Arboreal Lizards
- Family Chamaeleonidae – Chameleons
- Family Corytophanidae – Helmet Lizards
- Family Crotaphytidae – Collared Lizards, Leopard Lizards
- Family Hoplocercidae – Dwarf and Spiny Tail Iguanas
- Family Iguanidae – American Arboreal Lizards, Chuckwallas, Iguanas, Iguanids
- Family Opluridae – Malagasy Iguanas
- Family Phrynosomatidae – North American Spiny Lizards
- Family Polychrotidae – Anoles and kin
- Family Tropiduridae – Tropidurid Lizards

Gekkota

Active hunters, the Gekkota includes three families comprising the distinctive cosmopolitan geckos and the legless flap-footed lizards of Australia and New Zealand. Like snakes, the flap-footed lizards and most geckos lack eyelids. Unlike snakes, they use their tongues to clean their often highly developed eyes. While gecko feet have unique surfaces that allow them to cling to glass and run on ceilings, the flapfoot has lost its limbs. The three families of this suborder are:

- Family Eublepharidae – 'Eyelid' Geckos
- Family Gekkonidae – Geckos
- Family Pygopodidae – Flap-footed Lizards

Struggle with humans

Komodo dragons on Rinca

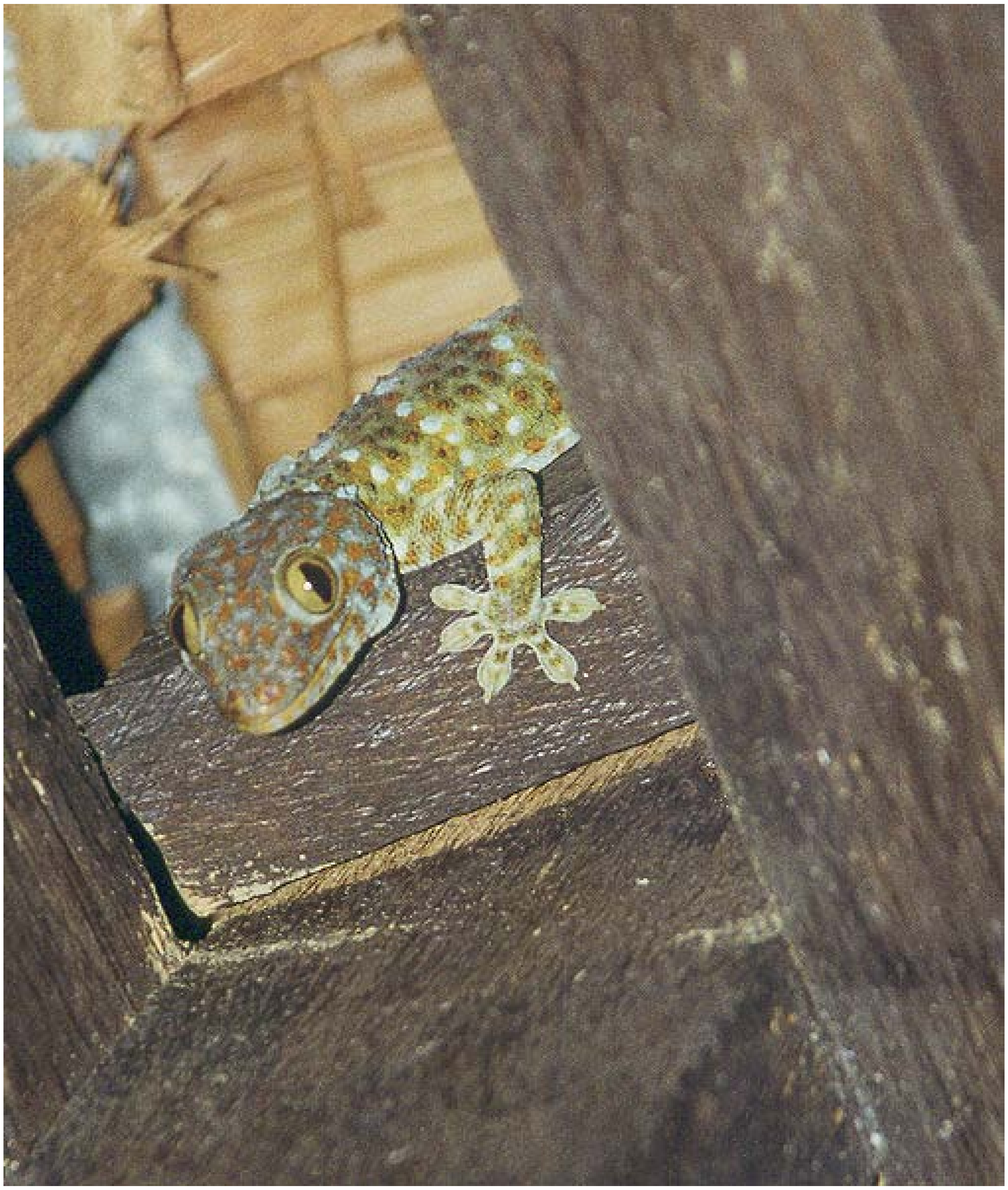
Green iguanas (*Iguana iguana*), are popular exotic pets

Most lizard species are harmless to humans. Only the very largest lizard species pose threat of death; the Komodo dragon, for example, has been known to stalk, attack, and, on occasion, kill humans. An eight-year-old Indonesian boy died from blood loss after an attack in 2007. The venom of the Gila monster and beaded lizard is not usually deadly but they can inflict extremely painful bites due to powerful jaws. Numerous species of lizard are kept as pets.

Lizard symbolism plays important though rarely predominant roles in some cultures (e.g., Tarrotarro in Australian Aboriginal mythology). The Moche people of ancient Peru worshiped animals and often depicted lizards in their art. According to a popular legend in Maharashtra, a Common Indian Monitor, with ropes attached, was used to scale the walls of the Sinhagad fort in the Battle of Sinhagad.

Green Iguanas are eaten in Central America and Uromastyx in Africa. In North Africa, Uromastyx are considered *dhaab* or 'fish of the desert' and eaten by nomadic tribes.

Classification



Gekko gecko in Thailand

Close-up of the head of the legless fossorial amphisbaenid *Rhineura*

Underside of a Thorny devil, an agamid, Western Australia

The Eastern blue-tongued lizard, a scincomorph

The venomous Gila monster, *Heloderma s. suspectum*

Oriental Garden Lizard in Malaysia

Suborder Lacertilia (Sauria) - (Lizards)

- Family †Bavarisauridae
- Family †Eichstaettisauridae
- Infraorder Iguania
    - Family †Arretosauridae
    - Family †Euposauridae
    - Family Corytophanidae (casquehead lizards)
    - Family Iguanidae (iguanas and spinytail iguanas)
    - Family Phrynosomatidae (earless, spiny, tree, side-blotched and horned lizards)
    - Family Polychrotidae (anoles)
        - Family Leiosauridae
    - Family Tropiduridae (neotropical ground lizards)
        - Family Liolaemidae
    - Family Leiocephalidae
    - Family Crotaphytidae (collared and leopard lizards)
    - Family Opluridae (Madagascar iguanids)
    - Family Hoplocercidae (wood lizards, clubtails)
    - Family †Priscagamidae

    - Family †Isodontosauridae
    - Family Agamidae (agamas)
    - Family Chamaeleonidae (chameleons)
- Infraorder Gekkota
    - Family Gekkonidae (geckos)
    - Family Pygopodidae (legless lizards)
    - Family Dibamidae (blind lizards)
- Infraorder Scincomorpha
    - Family †Paramacellodidae
    - Family †Slavoiidae
    - Family Scincidae (skinks)
    - Family Cordylidae (spinytail lizards)
    - Family Gerrhosauridae (plated lizards)
    - Family Xantusiidae (night lizards)
    - Family Lacertidae (wall lizards or true lizards)
    - Family †Mongolochamopidae
    - Family †Adamisauridae
    - Family Teiidae (tegus and whiptails)
    - Family Gymnophthalmidae (spectacled lizards)
- Infraorder Diploglossa
    - Family Anguidae (glass lizards)
    - Family Anniellidae (American legless lizards)
    - Family Xenosauridae (knob-scaled lizards)
- Infraorder Platynota (Varanoidea)
    - Family Varanidae (monitor lizards)
    - Family Lanthanotidae (earless monitor lizards)
    - Family Helodermatidae (gila monsters & beaded lizards)
    - Family †Mosasauridae (marine lizards)

Chapter- 4

Snake (Type of Reptile)

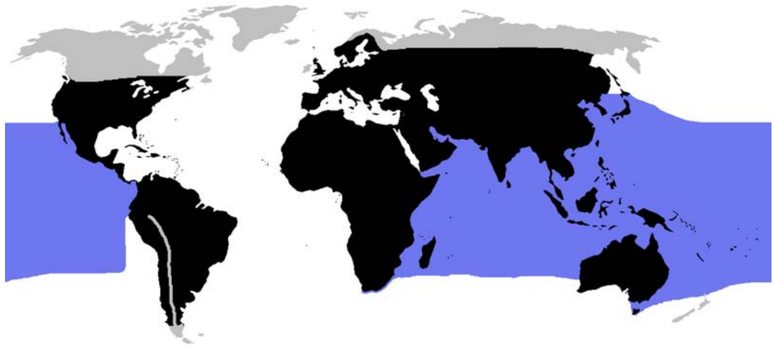
Snakes Temporal range: 145–0 Ma Cretaceous – Recent	

Coast garter snake,
Thamnophis elegans terrestris

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Squamata
Superfamily:	Varanoidea
(unranked):	Pythonomorpha
Suborder:	**Serpentes** Linnaeus, 1758

Infraorders

- Alethinophidia – Nopcsa, 1923
- Scolecophidia – Cope, 1864



World range of snakes
(rough range of sea snakes in blue)

Snakes are elongate, legless, carnivorous reptiles of the suborder **Serpentes** that can be distinguished from legless lizards by their lack of eyelids and external ears. Like all squamates, snakes are ectothermic, amniote vertebrates covered in overlapping scales. Many species of snakes have skulls with many more joints than their lizard ancestors, enabling them to swallow prey much larger than their heads with their highly mobile jaws. To accommodate their narrow bodies, snakes' paired organs (such as kidneys) appear one in front of the other instead of side by side, and most have only one functional lung. Some species retain a pelvic girdle with a pair of vestigial claws on either side of the cloaca.

Living snakes are found on every continent except Antarctica and on most islands. Fifteen families are currently recognized, comprising 456 genera and over 2,900 species. They range in size from the tiny, 10 cm-long thread snake to pythons and anacondas of up to 7.6 metres (25 ft) in length. The recently discovered fossil Titanoboa was 15 metres (49 ft) long. Snakes are thought to have evolved from either burrowing or aquatic lizards during the Cretaceous period (*c* 150 Ma). The diversity of modern snakes appeared during the Paleocene period (*c* 66 to 56 Ma).

Most species are nonvenomous and those that have venom use it primarily to kill and subdue prey rather than for self-defense. Some possess venom potent enough to cause painful injury or death to humans. Nonvenomous snakes either swallow prey alive or kill by constriction.

Etymology

The English word *snake* comes from Old English *snaca*, itself from Proto-Germanic **snak-an-* (cf. German *Schnake* "ring snake," Swedish *snok* "grass snake"), from Proto-Indo-European root **(s)nēg-o-* "to crawl, creep," which also gave *sneak* as well as Sanskrit *nāgá* "snake." The word ousted *adder*, as *adder* went on to narrow in meaning, though in Old English *nædre* was the general word for snake. The other term, *serpent*, is from French, ultimately from Indo-European **serp-* (to creep), which also gave Greek *érpo* (ερπω) "I crawl."

Evolution

The fossil record of snakes is relatively poor because snake skeletons are typically small and fragile, making fossilization uncommon. However, 150 million-year-old specimens, readily identifiable as snakes, yet with lizard-like skeletal structures, have been uncovered in South America and Africa.[:11] Based on comparative anatomy, there is consensus that snakes descended from lizards.[:11]

Pythons and boas—primitive groups among modern snakes—have vestigial hind limbs: tiny, clawed digits known as anal spurs, which are used to grasp during mating.[:11] The Leptotyphlopidae and Typhlopidae groups also possess remnants of the pelvic girdle, sometimes appearing as horny projections when visible.

Frontal limbs are nonexistent in all snakes. This is caused by the evolution of Hox genes, controlling limb morphogenesis. The axial skeleton of the snakes' common ancestor, like most other tetrapods, had regional specializations consisting of cervical (neck), thoracic (chest), lumbar (lower back), sacral (pelvic), and caudal (tail) vertebrae. Early in snake evolution, the Hox gene expression in the axial skeleton responsible for the development of the thorax became dominant. As a result, the vertebrae anterior to the hindlimb buds (when present) all have the same thoracic-like identity (except from the atlas, axis, and 1–3 neck vertebrae). In other words, most of a snake's skeleton is an extremely extended thorax. Ribs are found exclusively on the thoracic vertebrae. Neck, lumbar and pelvic vertebrae are very reduced in number (only 2–10 lumbar and pelvic vertebrae are present), while only a short tail remains of the caudal vertebrae. However, the tail is still long enough to be of important use in many species, and is modified in some aquatic and tree-dwelling species.

Modern snakes greatly diversified during the Paleocene. This occurred alongside the adaptive radiation of mammals, following the extinction of (non-avian) dinosaurs. The colubrids, one of the more common snake groups, became particularly diverse due to preying on rodents, an especially successful mammal group. There are over 2,900 species of snakes ranging as far northward as the Arctic Circle in Scandinavia and southward through Australia and Tasmania. Snakes can be found on every continent (with the exception of Antarctica), in the sea, and as high as 16,000 feet (4,900 m) in the Himalayan Mountains of Asia.[:143] There are numerous islands from which snakes are absent, such as Ireland, Iceland, and New Zealand.[:143]

Origins

The origin of snakes remains an unresolved issue. There are two main hypotheses competing for acceptance.

Burrowing Lizard Hypothesis

There is fossil evidence to suggest that snakes may have evolved from burrowing lizards, such as the varanids (or a similar group) during the Cretaceous Period. An early fossil snake, *Najash rionegrina*, was a two-legged burrowing animal with a sacrum, and was fully terrestrial. One extant analog of these putative ancestors is the earless monitor *Lanthanotus* of Borneo (though it also is semiaquatic). Subterranean species evolved bodies streamlined for burrowing, and eventually lost their limbs. According to this hypothesis, features such as the transparent, fused eyelids (brille) and loss of external ears evolved to cope with fossorial difficulties, such as scratched corneas and dirt in the ears. Some primitive snakes are known to have possessed hindlimbs, but their pelvic bones lacked a direct connection to the vertebrae. These include fossil species like *Haasiophis*, *Pachyrhachis* and *Eupodophis*, which are slightly older than *Najash*.

Fossil of *Archaeophis proavus*.

Aquatic Mosasaur Hypothesis

An alternative hypothesis, based on morphology, suggests the ancestors of snakes were related to mosasaurs—extinct aquatic reptiles from the Cretaceous—which in turn are thought to have derived from varanid lizards. According to this hypothesis, the fused, transparent eyelids of snakes are thought to have evolved to combat marine conditions (corneal water loss through osmosis), and the external ears were lost through disuse in an aquatic environment. This ultimately lead to an animal similar to today's sea snakes. In the Late Cretaceous, snakes recolonized land, and continued to diversify into today's snakes. Fossilized snake remains are known from early Late Cretaceous marine sediments, which is consistent with this hypothesis; particularly so, as they are older than the terrestrial *Najash rionegrina*. Similar skull structure, reduced or absent limbs, and other anatomical features found in both mosasaurs and snakes lead to a positive cladistical correlation, although some of these features are shared with varanids.

Genetic studies in recent years have indicated snakes are not as closely related to monitor lizards as was once believed—and therefore not to mosasaurs, the proposed ancestor in the aquatic scenario of their evolution. However, more evidence links mosasaurs to snakes than to varanids. Fragmented remains found from the Jurassic and Early Cretaceous indicate deeper fossil records for these groups, which may potentially refute either hypothesis.

Taxonomy

All modern snakes are grouped within the suborder *Serpentes* in Linnean taxonomy, part of the order Squamata, though their precise placement within squamates is controversial.

There are two infraorders of *Serpentes*: Alethinophidia and Scolecophidia. This separation is based on morphological characteristics and mitochondrial DNA sequence similarity. Alethinophidia is sometimes split into Henophidia and Caenophidia, with the latter consisting of "colubroid" snakes (colubrids, vipers, elapids, hydrophiids, and attractaspids) and acrochordids, while the other alethinophidian families comprise Henophidia. While not extant today, the Madtsoiidae, a family of giant, primitive, python-like snakes, was around until 50,000 years ago in Australia, represented by genera such as Wonambi.

There are numerous debates in the systematics within the group. For instance, many sources classify Boidae and Pythonidae as one family, while some keep the Elapidae and Hydrophiidae (sea snakes) separate for practical reasons despite their extremely close relation.

Recent molecular studies support the monophyly of the clades of modern snakes, scolecophidians, typhlopids + anomalepidids, alethinophidians, core alethinophidians, uropeltids (*Cylindrophis*, *Anomochilus*, uropeltines), macrostomatans, booids, boids, pythonids and caenophidians.

Families

Infraorder **Alethinophidia** 15 families					
Family	**Taxon author**	**Genera**	**Species**	**Common name**	**Geographic range**
Acrochordidae	Bonaparte, 1831	1	3	Wart snakes	Western India and Sri Lanka through tropical Southeast Asia to the Philippines, south through the Indonesian/Malaysian island group to Timor, east through New Guinea to the northern coast of Australia to Mussau Island, the Bismark Archipelago and Guadalcanal Island in the Solomon Islands.
Aniliidae	Stejneger, 1907	1	1	False coral snake	Tropical South America.
Anomochilidae	Cundall, Wallach, 1993	1	2	Dwarf pipe snakes	West Malaysia and on the Indonesian island of Sumatra.
Atractaspididae	Günther, 1858	12	64	Burrowing asps	Africa and the Middle East.
Boidae	Gray, 1825	8	43	Boas	Northern, Central and South America, the Caribbean, southeastern Europe and Asia Minor, Northern, Central and East Africa, Madagascar and Reunion Island, the Arabian Peninsula, Central and southwestern Asia, India and Sri Lanka, the Moluccas and New Guinea through to Melanesia and Samoa.
Bolyeriidae	Hoffstetter, 1946	2	2	Splitjaw snakes	Mauritius.
Colubridae	Oppel, 1811	304	1938	Typical snakes	Widespread on all continents, except Antarctica.
Cylindrophiidae	Fitzinger, 1843	1	8	Asian pipe snakes	Sri Lanka east through Myanmar, Thailand, Cambodia, Vietnam and the

					Malay Archipelago to as far east as Aru Islands off the southwestern coast of New Guinea. Also found in southern China (Fujian, Hong Kong and on Hainan Island) and in Laos.
Elapidae	Boie, 1827	61	235	Elapids	On land, worldwide in tropical and subtropical regions, except in Europe. Sea snakes occur in the Indian Ocean and the Pacific.
Loxocemidae	Cope, 1861	1	1	Mexican burrowing snake	Along the Pacific versant from Mexico south to Costa Rica.
Pythonidae	Fitzinger, 1826	8	26	Pythons	Subsaharan Africa, India, Myanmar, southern China, Southeast Asia and from the Philippines southeast through Indonesia to New Guinea and Australia.
Tropidophiidae	Brongersma, 1951	4	22	Dwarf boas	From southern Mexico and Central America, south to northwestern South America in Colombia, (Amazonian) Ecuador and Peru, as well as in northwestern and southeastern Brazil. Also found in the West Indies.
Uropeltidae	Müller, 1832	8	47	Shield-tailed snakes	Southern India and Sri Lanka.
Viperidae	Oppel, 1811	32	224	Vipers	The Americas, Africa and Eurasia.
Xenopeltidae	Bonaparte, 1845	1	2	Sunbeam snakes	Southeast Asia from the Andaman and Nicobar Islands, east through Myanmar to southern China, Thailand, Laos, Cambodia, Vietnam, the Malay Peninsula and the East Indies to Sulawesi, as well as the Philippines.

Infraorder **Scolecophidia** 3 families					
Family	**Taxon author**	**Genera**	**Species**	**Common name**	**Geographic range**
Anomalepidae	Taylor, 1939	4	15	Primitive blind snakes	From southern Central America to northwestern South America. Disjunct populations in northeastern and southeastern South America.
Leptotyphlopidae	Stejneger, 1892	2	87	Slender blind snakes	Africa, western Asia from Turkey to northwestern India, on Socotra Island, from the southwestern United States south through Mexico and Central to South America, though not in the high Andes. In Pacific South America they occur as far south as southern coastal Peru, and on the Atlantic side as far as Uruguay and Argentina. In the Caribbean they are found on the Bahamas, Hispaniola and the Lesser Antilles.
Typhlopidae	Merrem, 1820	6	203	Typical blind snakes	Most tropical and many subtropical regions around the world, particularly in Africa, Madagascar, Asia, islands in the Pacific, tropical America and in southeastern Europe.

Biology

When compared, the skeletons of snakes are radically different from those of most other reptiles (such as the turtle, right), being made up almost entirely of an extended ribcage.

Skeleton

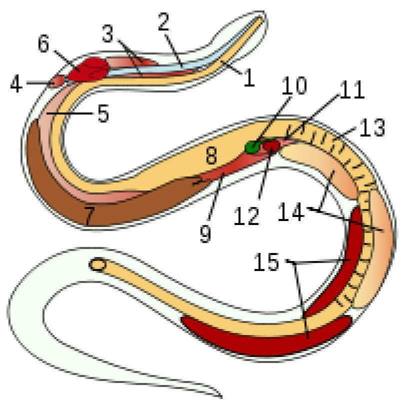
The skeleton of most snakes consists solely of the skull, hyoid, vertebral column, and ribs, though henophidian snakes retain vestiges of the pelvis and rear limbs. The skull of the snake consists of a solid and complete braincase, to which many of the other bones are only loosely attached, particularly the highly mobile jaw bones, which facilitate manipulation and ingestion of large prey items. The left and right sides of the lower jaw are joined only by a flexible ligament at the anterior tips, allowing them to separate widely, while the posterior end of the lower jaw bones articulate with a quadrate bone, allowing further mobility. The bones of the mandible and quadrate bones can also pick up ground borne vibrations. The hyoid is a small bone located posterior and ventral to the skull, in the 'neck' region, which serves as an attachment for muscles of the snake's tongue, as it does in all other tetrapods.

The vertebral column consists of anywhere between 200 to 400 (or more) vertebrae. Tail vertebrae are comparatively few in number (often less than 20% of the total) and lack ribs, while body vertebrae each have two ribs articulating with them. The vertebrae have projections that allow for strong muscle attachment enabling locomotion without limbs.

Autotomy of the tail, a feature found in some lizards is absent in most snakes. Caudal autotomy in snakes is rare and is intervertebral, unlike that in lizards, which is intravertebral—that is, the break happens along a predefined fracture plane present on a vertebra.

In some snakes, most notably boas and pythons, there are vestiges of the hindlimbs in the form of a pair of pelvic spurs. These small, claw-like protrusions on each side of the cloaca are the external portion of the vestigial hindlimb skeleton, which includes the remains of an ilium and femur.

Internal organs



Anatomy of a snake. 1 esophagus, 2 trachea, 3 tracheal lungs, 4 rudimentary left lung, 5 right lung, 6 heart, 7 liver, 8 stomach, 9 air sac, 10 gallbladder, 11 pancreas, 12 spleen, 13 intestine, 14 testicles, 15 kidneys.

The snake's heart is encased in a sac, called the *pericardium*, located at the bifurcation of the bronchi. The heart is able to move around, however, owing to the lack of a diaphragm. This adjustment protects the heart from potential damage when large ingested prey is passed through the esophagus. The spleen is attached to the gall bladder and pancreas and filters the blood. The thymus gland is located in fatty tissue above the heart and is responsible for the generation of immune cells in the blood. The cardiovascular system of snakes is also unique for the presence of a renal portal system in which the blood from the snake's tail passes through the kidneys before returning to the heart.

The vestigial left lung is often small or sometimes even absent, as snakes' tubular bodies require all of their organs to be long and thin. In the majority of species, only one lung is functional. This lung contains a vascularized anterior portion and a posterior portion that does not function in gas exchange. This 'saccular lung' is used for hydrostatic purposes to adjust buoyancy in some aquatic snakes and its function remains unknown in terrestrial species. Many organs that are paired, such as kidneys or reproductive organs, are staggered within the body, with one located ahead of the other.

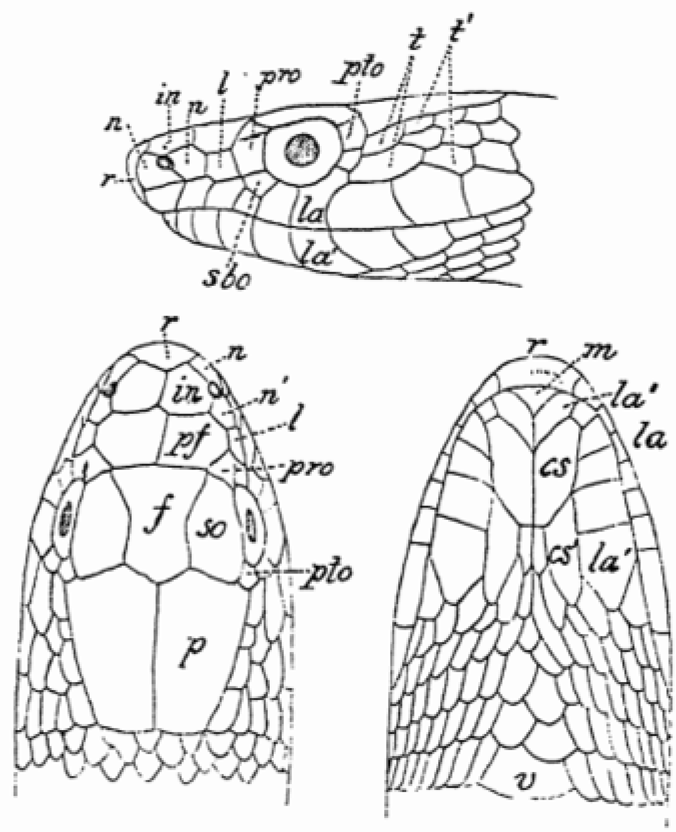
Snakes have no lymph nodes.

An adult Barbados threadsnake, Leptotyphlops carlae, on an American quarter dollar.

Size

The now extinct *Titanoboa cerrejonensis* snakes found were 12–15 meters (39–49 ft) in length. By comparison, the largest extant snakes are the reticulated python, which measures about 9 meters (30 ft) long, and the anaconda, which measures about 7.5 meters (25 ft) long and is considered the heaviest snake on Earth.

At the other end of the scale, the smallest extant snake is *Leptotyphlops carlae*, with a length of about 10 centimeters (4 in). Most snakes are fairly small animals, approximately 3 feet in length.



Three views of head of *Zamenis ventrimaculatus*, to explain the terminology of the head-shields.

cs. Chin-shields (anterior).
cs'. Chin-shields (posterior).
f. Frontal.
in. Internasal.
l. Loreal.
la. Upper labial.
la'. Lower labial.
m. Mental.
n. Nasal.
p. Parietal.
pf. Præfrontal.
pro. Præocular.
pto. Postocular.
r. Rostral.
sbo. Subocular.
so. Supraocular.
t. Temporals (first row).
t'. Temporals (second row).
v. First ventral.

A line diagram from G.A. Boulenger's Fauna of British India (1890) illustrating the terminology of shields on the head of a snake.

Skin

The skin of a snake is covered in scales. Contrary to the popular notion of snakes being slimy because of possible confusion of snakes with worms, snakeskin has a smooth, dry texture. Most snakes use specialized belly scales to travel, gripping surfaces. The body scales may be smooth, keeled, or granular. The eyelids of a snake are transparent "spectacle" scales, which remain permanently closed, also known as brille.

The shedding of scales is called *ecdysis* (or in normal usage, *moulting* or *sloughing*). In the case of snakes, the complete outer layer of skin is shed in one layer. Snake scales are not discrete, but extensions of the epidermis—hence they are not shed separately but as a complete outer layer during each moult, akin to a sock being turned inside out.

The shape and number of scales on the head, back, and belly are often characteristic and used for taxonomic purposes. Scales are named mainly according to their positions on the body. In "advanced" (Caenophidian) snakes, the broad belly scales and rows of dorsal scales correspond to the vertebrae, allowing scientists to count the vertebrae without dissection.

Eye scales visible during the moult of a Diamond Python.

Snakes' eyes are covered by their clear scales (the brille) rather than movable eyelids. Their eyes are always open, and for sleeping, the retina can be closed or the face buried among the folds of the body.

Moulting

Moulting serves a number of functions. Firstly, the old and worn skin is replaced; secondly, it helps get rid of parasites such as mites and ticks. Renewal of the skin by moulting is supposed to allow growth in some animals such as insects; however, this has been disputed in the case of snakes.

A snake shedding its skin.

Moulting occurs periodically throughout a snake's life. Before a moult, the snake stops eating and often hides or moves to a safe place. Just before shedding, the skin becomes dull and dry looking and the eyes become cloudy or blue-colored. The inner surface of the old skin liquefies. This causes the old skin to separate from the new skin beneath it. After a few days, the eyes clear and the snake "crawls" out of its old skin. The old skin breaks near the mouth and the snake wriggles out, aided by rubbing against rough surfaces. In many cases, the cast skin peels backward over the body from head to tail in one piece, like pulling a sock off inside-out. A new, larger, brighter layer of skin has formed underneath.

An older snake may shed its skin only once or twice a year. But a younger snake, still growing, may shed up to four times a year. The discarded skin gives a perfect imprint of the scale pattern, and it is usually possible to identify the snake if the discarded skin is reasonably intact. This periodic renewal has led to the snake being a symbol of healing and medicine, as pictured in the Rod of Asclepius.

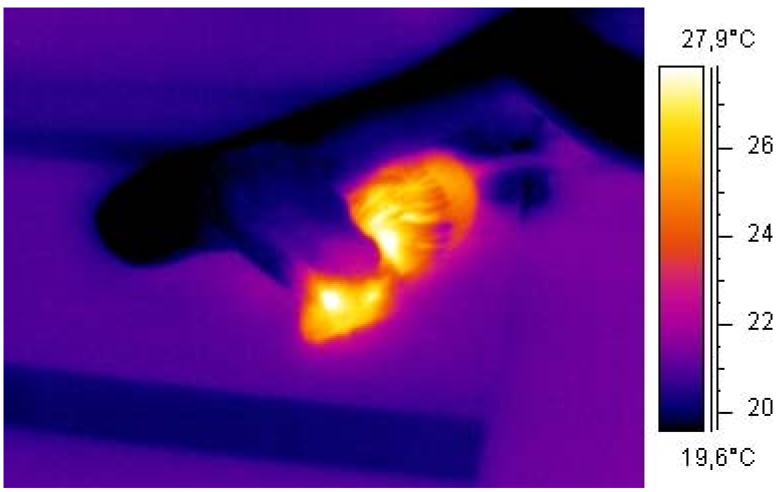
Perception

Eyesight

Snake vision varies greatly, from only being able to distinguish light from dark to keen eyesight, but the main trend is that their vision is adequate although not sharp, and allows them to track movements. Generally, vision is best in arboreal snakes and weakest in burrowing snakes. Some snakes, such as the Asian vine snake (genus *Ahaetulla*), have binocular vision, with both eyes capable of focusing on the same point. Most snakes focus by moving the lens back and forth in relation to the retina, while in the other amniote groups, the lens is stretched.

Smell

Snakes use smell to track their prey. They smell by using their forked tongues to collect airborne particles, then passing them to the vomeronasal organ or *Jacobson's organ* in the mouth for examination. The fork in the tongue gives snakes a sort of directional sense of smell and taste simultaneously. They keep their tongues constantly in motion, sampling particles from the air, ground, and water, analyzing the chemicals found, and determining the presence of prey or predators in the local environment.



Thermographic image of a snake eating a mouse

Vibration sensitivity

The part of the body in direct contact with the ground is very sensitive to vibration; thus, a snake can sense other animals approaching by detecting faint vibrations in the air and on the ground.

Infrared sensitivity

Pit vipers, pythons, and some boas have infrared-sensitive receptors in deep grooves between the nostril and eye, although some have labial pits on their upper lip just below the nostrils (common in pythons), which allow them to "see" the radiated heat of warm-blooded prey mammals.

Venom

Milk snakes are often mistaken for coral snakes, whose venom is deadly to humans.

Cobras, vipers, and closely related species use venom to immobilize or kill their prey. The venom is modified saliva, delivered through fangs.[:243] The fangs of 'advanced' venomous snakes like viperids and elapids are hollow to inject venom more effectively, while the fangs of rear-fanged snakes such as the boomslang merely have a groove on the posterior edge to channel venom into the wound. Snake venoms are often prey specific, their role in self-defense is secondary.[:243]

Venom, like all salivary secretions, is a predigestant that initiates the breakdown of food into soluble compounds, facilitating proper digestion. Even nonvenomous snake bites (like any animal bite) will cause tissue damage.[:209]

Certain birds, mammals, and other snakes (such as kingsnakes) that prey on venomous snakes have developed resistance and even immunity to certain venoms.[:243] Venomous snakes include three families of snakes, and do not constitute a formal classification group used in taxonomy.

The term **poisonous snake** is mostly incorrect. Poison is inhaled or ingested, whereas venom is injected. There are, however, two exceptions: *Rhabdophis* sequesters toxins from the toads it eats, then secretes them from nuchal glands to ward off predators, and a small population of garter snakes in Oregon retains enough toxin in their liver from the newts they eat to be effectively poisonous to small local predators (such as crows and foxes).

Snake venoms are complex mixtures of proteins, and are stored in poison glands at the back of the head. In all venomous snakes, these glands open through ducts into grooved or hollow teeth in the upper jaw.[:243] These proteins can potentially be a mix of neurotoxins (which attack the nervous system), hemotoxins (which attack the circulatory system), cytotoxins, bungarotoxins and many other toxins that affect the body in different ways. Almost all snake venom contains *hyaluronidase*, an enzyme that ensures rapid diffusion of the venom.

Venomous snakes that use hemotoxins usually have fangs in the front of their mouths, making it easier for them to inject the venom into their victims. Some snakes that use neurotoxins (such as the mangrove snake) have fangs in the back of their mouths, with the fangs curled backwards. This makes it both difficult for the snake to use its venom and for scientists to milk them. *Elapids*, however, such as cobras and kraits are *proteroglyphous*—they possess hollow fangs that cannot be erected toward the front of their mouths, and cannot "stab" like a viper. They must actually bite the victim.

It has recently been suggested that all snakes may be venomous to a certain degree, with harmless snakes having weak venom and no fangs. Most snakes currently labelled "nonvenomous" would still be considered harmless according to this theory, as they either lack a venom delivery method or are incapable of delivering enough to endanger a human. This theory postulates that snakes may have evolved from a common lizard ancestor that was venomous—and that venomous lizards like the gila monster, beaded lizard, monitor lizards, and the now-extinct mosasaurs may also have derived. They share this venom clade with various other saurian species.

Venomous snakes are classified in two taxonomic families:

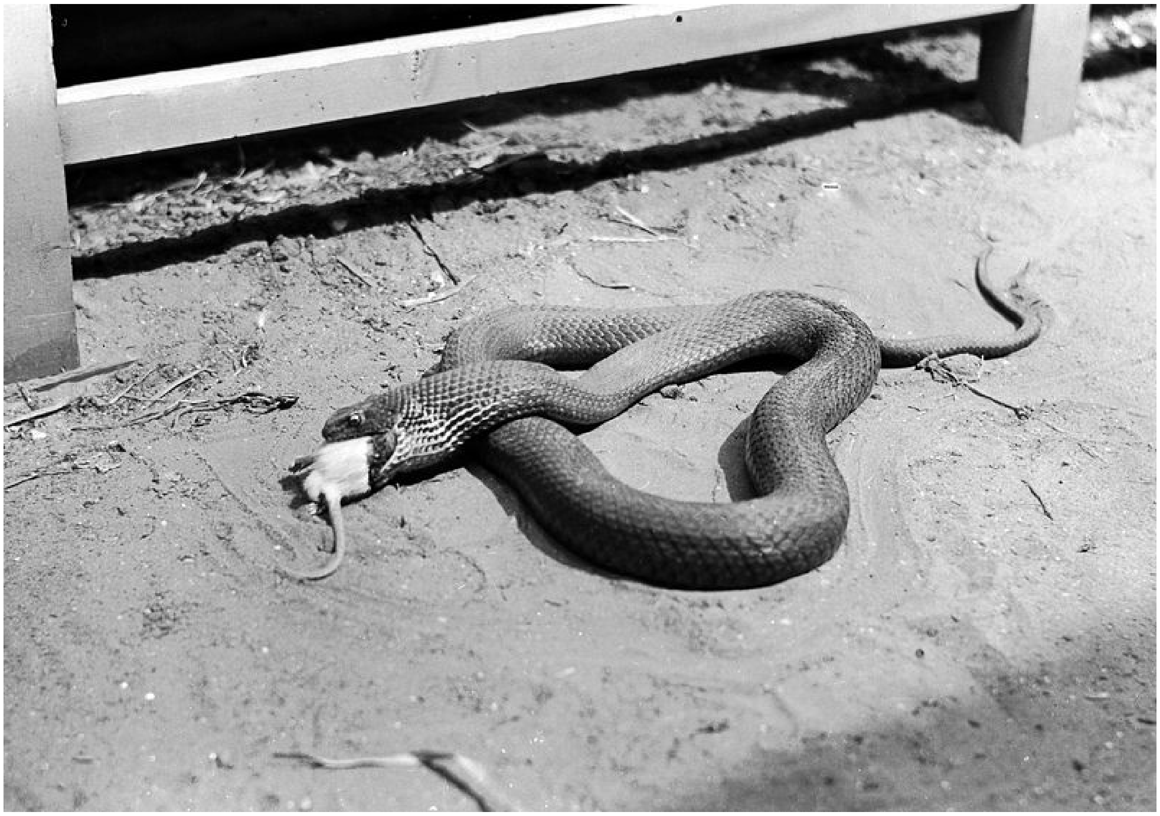
- Elapids – cobras including king cobras, kraits, mambas, Australian copperheads, sea snakes, and coral snakes.
- Viperids – vipers, rattlesnakes, copperheads/cottonmouths, adders and bushmasters.

There is a third family containing the *opistoglyphous* (rear-fanged) snakes (as well as the majority of other snake species):

- Colubrids – boomslangs, tree snakes, vine snakes, mangrove snakes, although not all colubrids are venomous.[:209]

Behavior

Feeding and diet



Snake eating a rodent.

Carpet python constricting and consuming a chicken.

All snakes are strictly carnivorous, eating small animals including lizards, other snakes, small mammals, birds, eggs, fish, snails or insects. Because snakes cannot bite or tear their food to pieces, they must swallow prey whole. The body size of a snake has a major influence on its eating habits. Smaller snakes eat smaller prey. Juvenile pythons might start out feeding on lizards or mice and graduate to small deer or antelope as an adult, for example.

African egg-eating snake.

The snake's jaw is a complex structure. Contrary to the popular belief that snakes can dislocate their jaws, snakes have a very flexible lower jaw, the two halves of which are not rigidly attached, and numerous other joints in their skull, allowing them to open their mouths wide enough to swallow their prey whole, even if it is larger in diameter than the snake itself, as snakes do not chew. For example, the African egg-eating snake has flexible jaws adapted for eating eggs much larger than the diameter of its head. This snake has no teeth, but does have bony protrusions on the inside edge of its spine, which it uses to break shells when it eats eggs.

While the majority of snakes eat a variety of prey animals, there is some specialization by some species. King cobras and the Australian bandy-bandy consume other snakes.

Pareas iwesakii and other snail-eating colubrids of subfamily Pareatinae have more teeth on the right side of their mouths than on the left, as the shells of their prey usually spiral clockwise.

Some snakes have a venomous bite, which they use to kill their prey before eating it. Other snakes kill their prey by constriction. Still others swallow their prey whole and alive.

After eating, snakes become dormant while the process of digestion takes place. Digestion is an intense activity, especially after consumption of large prey. In species that feed only sporadically, the entire intestine enters a reduced state between meals to conserve energy. The digestive system is then 'up-regulated' to full capacity within 48 hours of prey consumption. Being ectothermic ("cold-blooded"), the surrounding temperature plays a large role in snake digestion. The ideal temperature for snakes to digest is 30 °C (86 °F). So much metabolic energy is involved in a snake's digestion that in the Mexican rattlesnake (*Crotalus durissus*), surface body temperature increases by as much as 1.2 °C (2.2 °F) during the digestive process. Because of this, a snake disturbed after having eaten recently will often regurgitate its prey to be able to escape the perceived threat. When undisturbed, the digestive process is highly efficient, with the snake's digestive enzymes dissolving and absorbing everything but the prey's hair (or feathers) and claws, which are excreted along with waste.

Chapter- 5

Turtle (Type of Reptile)

Turtles Temporal range: Late Triassic - Recent, 215–0 Ma	

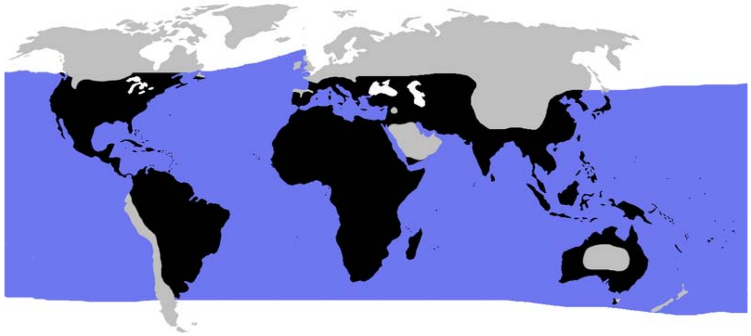
Florida Box Turtle *Terrapene carolina*

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Superorder:	**Chelonia** Macartney, 1802
Order:	**Testudines** Linnaeus, 1758

Suborders
Cryptodira Pleurodira

Diversity

14 extant families with ca. 300 species



blue: sea turtles, black: land turtles

Turtles are reptiles of the order **Testudines** (the crown group of the superorder **Chelonia**), characterised by a special bony or cartilaginous shell developed from their ribs that acts as a shield. "Turtle" may either refer to the Testudines as a whole, or to particular Testudines which make up a form taxon that is not monophyletic.

The order Testudines includes both extant (living) and extinct species. The earliest known turtles date from 215 million years ago, making turtles one of the oldest reptile groups and a more ancient group than lizards, snakes and crocodiles. Of the many species alive today some are highly endangered.

Like other reptiles, turtles are ectotherms—varying their internal temperature according to the ambient environment, commonly called cold-blooded. However, leatherback sea turtles have noticeably higher body temperature than surrounding water because of their high metabolic rate.

Like other amniotes (reptiles, dinosaurs, birds, and mammals), they breathe air and do not lay eggs underwater, although many species live in or around water. The largest turtles are aquatic.

Anatomy and morphology

Chelonia mydas in Kona, Hawaii.

The largest living chelonian is the great leatherback sea turtle (*Dermochelys coriacea*), which reaches a shell length of 200 centimetres (6.6 ft) and can reach a weight of over 900 kilograms (2,000 lb). Freshwater turtles are generally smaller, but with the largest species, the Asian softshell turtle *Pelochelys cantorii*, a few individuals have been reported up to 200 centimetres (6.6 ft). This dwarfs even the better-known alligator snapping turtle, the largest chelonian in North America, which attains a shell length of up to 80 centimetres (2.6 ft) and a weight of about 60 kilograms (130 lb). Giant tortoises of the genera *Geochelone*, *Meiolania*, and others were relatively widely distributed around the world into prehistoric times, and are known to have existed in North and South America, Australia, and Africa. They became extinct at the same time as the appearance of man, and it is assumed that humans hunted them for food. The only surviving giant tortoises are on the Seychelles and Galápagos Islands, and can grow to over 130 centimetres (51 in) in length, and weigh about 300 kilograms (660 lb).

The largest ever chelonian was *Archelon ischyros*, a Late Cretaceous sea turtle known to have been up to 4.6 metres (15 ft) long.

The smallest turtle is the speckled padloper tortoise of South Africa. It measures no more than 8 centimetres (3.1 in) in length and weighs about 140 grams (4.9 oz). Two other species of small turtles are the American mud turtles and musk turtles that live in an area that ranges from Canada to South America. The shell length of many species in this group is less than 13 centimetres (5.1 in) in length.

A turtle with eyes closer to the end of the head. Keeping only the nostrils and the eyes above the water surface.

African Spurred Tortoise in the zoo of Sharm el-Sheikh.

African Spurred Tortoise at a zoo in the Czech Republic.

Neck folding

Turtles are divided into two groups, according to how they evolved a solution to the problem of withdrawing their necks into their shells (something the ancestral *Proganochelys* could not do): the Cryptodira, which can draw their necks in while contracting it under their spine; and the Pleurodira, which contract their necks to the side.

Head

Most turtles that spend most of their life on land have their eyes looking down at objects in front of them. Some aquatic turtles, such as snapping turtles and soft-shelled turtles, have eyes closer to the top of the head. These species of turtles can hide from predators in shallow water where they lie entirely submerged except for their eyes and nostrils. Sea turtles possess glands near their eyes that produce salty tears that rid their body of excess salt taken in from the water they drink.

Turtles are thought to have exceptional night vision due to the unusually large number of rod cells in their retinas. Turtles have color vision with a wealth of cone subtypes with sensitivities ranging from the near ultraviolet (UV A) to red. Some land turtles have very poor pursuit movement abilities, which are normally reserved for predators that hunt quick moving prey, but carnivorous turtles are able to move their heads quickly to snap.

Turtles have a rigid beak. Turtles use their jaws to cut and chew food. Instead of teeth, the upper and lower jaws of the turtle are covered by horny ridges. Carnivorous turtles usually have knife-sharp ridges for slicing through their prey. Herbivorous turtles have serrated-edged ridges that help them cut through tough plants. Turtles use their tongues to swallow food, but they cannot, unlike most reptiles, stick out their tongues to catch food.

Shell

The upper shell of the turtle is called the *carapace*. The lower shell that encases the belly is called the *plastron*. The carapace and plastron are joined together on the turtle's sides by bony structures called *bridges*. The inner layer of a turtle's shell is made up of about 60 bones that include portions of the backbone and the ribs, meaning the turtle cannot crawl out of its shell. In most turtles, the outer layer of the shell is covered by horny scales called scutes that are part of its outer skin, or epidermis. Scutes are made up of a fibrous protein called keratin that also makes up the scales of other reptiles. These scutes overlap the seams between the shell bones and add strength to the shell. Some turtles do not have horny scutes. For example, the Leatherback turtle and the soft-shelled turtles have shells covered with leathery skin instead.

The rigid shell means turtles cannot breathe as other reptiles do, by changing the volume of their chest cavity via expansion and contraction of the ribs. Instead, turtles breathe in two ways. First, they employ buccal pumping, pulling air into their mouth then pushing it into the lungs via oscillations of the floor of the throat. Secondly, by contracting the abdominal muscles that cover the posterior opening of the shell, the internal volume of the shell increases, drawing air into the lungs, allowing these muscles to function in much the same way as the mammalian diaphragm.

The shape of the shell gives helpful clues to how the turtle lives. Most tortoises have a large dome-shaped shell that makes it difficult for predators to crush the shell between their jaws. One of the few exceptions is the African pancake tortoise, which has a flat, flexible shell that allows it to hide in rock crevices. Most aquatic turtles have flat, streamlined shells which aid in swimming and diving. American snapping turtles and musk turtles have small, cross-shaped plastrons that give them more efficient leg movement for walking along the bottom of ponds and streams.

The color of a turtle's shell may vary. Shells are commonly colored brown, black, or olive green. In some species, shells may have red, orange, yellow, or grey markings and these markings are often spots, lines, or irregular blotches. One of the most colorful turtles is the eastern painted turtle which includes a yellow plastron and a black or olive shell with red markings around the rim.

Tortoises, being land-based, have rather heavy shells. In contrast, aquatic and soft-shelled turtles have lighter shells that help them avoid sinking in water and swim faster with more agility. These lighter shells have large spaces called fontanelles between the shell bones. The shells of leatherback turtles are extremely light because they lack scutes and contain many fontanelles.

Skin and molting

Snapping Turtle Tail. Blue Hills Reservation, Massachusetts.

As mentioned above, the outer layer of the shell is part of the skin; each scute (or plate) on the shell corresponds to a single modified scale. The remainder of the skin is composed of skin with much smaller scales, similar to the skin of other reptiles. Turtles do not molt their skins all at once, as snakes do, but continuously, in small pieces. When kept in aquaria, small sheets of dead skin can be seen in the water (often appearing to be a thin piece of plastic) having been sloughed off when the animal deliberately rubs itself against a piece of wood or stone. Tortoises also shed skin, but a lot of dead skin is allowed to accumulate into thick knobs and plates that provide protection to parts of the body outside the shell.

By counting the rings formed by the stack of smaller, older scutes on top of the larger, newer ones, it is possible to estimate the age of a turtle, if one knows how many scutes are produced in a year. This method is not very accurate, partly because growth rate is not constant, but also because some of the scutes eventually fall away from the shell.

Limbs

Terrestrial tortoises have short, sturdy feet. Tortoises are famous for moving slowly, in part because of their heavy, cumbersome shell, which restricts stride length.

The amphibious turtles normally have limbs similar to those of tortoises, except the feet are webbed and often have long claws. These turtles swim using all four feet in a way similar to the dog paddle, with the feet on the left and right side of the body alternately providing thrust. Large turtles tend to swim less than smaller ones, and the very big species, such as alligator snapping turtles, hardly swim at all, preferring to simply walk along the bottom of the river or lake. As well as webbed feet, turtles have very long claws, used to help them clamber onto riverbanks and floating logs, upon which they like to bask. Male turtles tend to have particularly long claws, and these appear to be used to stimulate the female while mating. While most turtles have webbed feet, some, such as the pig-nosed turtle, have true flippers, with the digits being fused into paddles and the claws being relatively small. These species swim in the same way as sea turtles.

Sea turtles are almost entirely aquatic and have flippers instead of feet. Sea turtles fly through the water, using the up-and-down motion of the front flippers to generate thrust; the back feet are not used for propulsion, but may be used as rudders for steering. Compared with freshwater turtles, sea turtles have very limited mobility on land, and apart from the dash from the nest to the sea as hatchlings, male sea turtles normally never leave the sea. Females must come back onto land to lay eggs. They move very slowly and laboriously, dragging themselves forwards with their flippers.

Ecology and life history

Sea turtle swimming

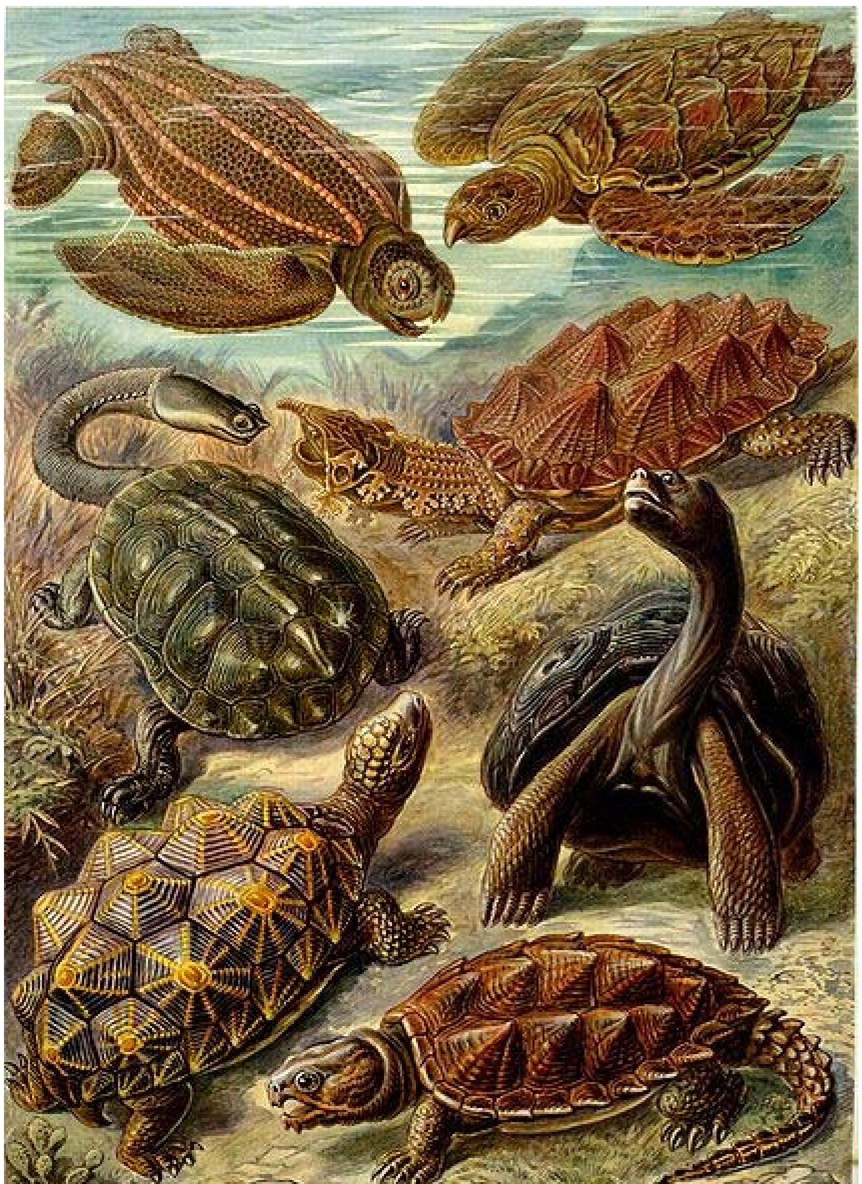
Although many turtles spend large amounts of their lives underwater, all turtles and tortoises breathe air, and must surface at regular intervals to refill their lungs. They can also spend much of their lives on dry land. Aquatic respiration in Australian freshwater turtles is currently being studied. Some species have large cloacal cavities that are lined with many finger-like projections. These projections, called papillae, have a rich blood supply, and increase the surface area of the cloaca. The turtles can take up dissolved oxygen from the water using these papillae, in much the same way that fish use gills to respire.

Turtles lay eggs, like other reptiles, which are slightly soft and leathery. The eggs of the largest species are spherical, while the eggs of the rest are elongated. Their albumen is white and contains a different protein from bird eggs, such that it will not coagulate when cooked. Turtle eggs prepared to eat consist mainly of yolk. In some species, temperature determines whether an egg develops into a male or a female: a higher temperature causes a female, a lower temperature causes a male. Large numbers of eggs are deposited in holes dug into mud or sand. They are then covered and left to incubate by themselves. When the turtles hatch, they squirm their way to the surface and head toward the water. There are no known species in which the mother cares for the young.

Sea turtles lay their eggs on dry, sandy beaches. Immature sea turtles are not cared for by the adults. Turtles can take many years to reach breeding age, and in many cases breed every few years rather than annually.

Researchers have recently discovered a turtle's organs do not gradually break down or become less efficient over time, unlike most other animals. It was found that the liver, lungs, and kidneys of a centenarian turtle are virtually indistinguishable from those of its immature counterpart. This has inspired genetic researchers to begin examining the turtle genome for longevity genes.

Systematics and evolution



"Chelonia" (Testudines) from Ernst Haeckel's *Kunstformen der Natur*, 1904.

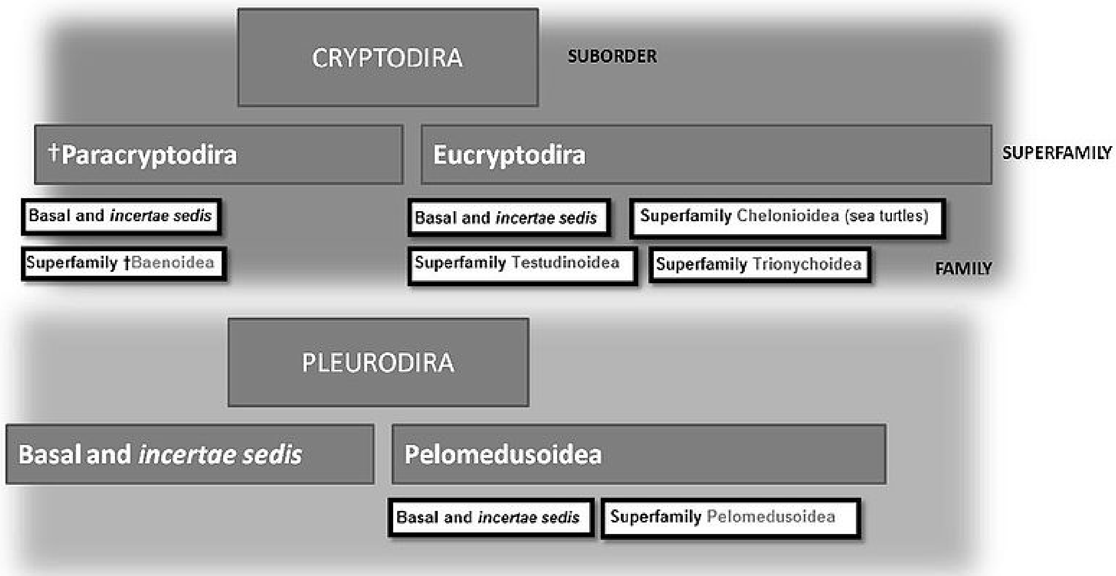
The first proto-turtles are believed to have existed in the late Triassic Period of the Mesozoic era, about 220 million years ago, and their shell, which has remained a remarkably stable body plan, is thought to have evolved from bony extensions of their backbones and broad ribs that expanded and grew together to form a complete shell that offered protection at every stage of its evolution, even when the bony component of the shell was not complete. This is supported by fossils of the freshwater *Odontochelys semitestacea* or "half-shelled turtle with teeth", from the late Triassic, which have been found near Guangling in south-west China. *Odontochelys* displays a complete bony plastron and an incomplete carapace, similar to an early stage of turtle embryonic development. Prior to this discovery, the earliest-known fossil turtles were terrestrial and had a complete shell, offering no clue to the evolution of this remarkable anatomical feature. By the late Jurassic, turtles had radiated widely, and their fossil history becomes easier to read.

Their exact ancestry has been disputed. It was believed that they are the only surviving branch of the ancient evolutionary grade Anapsida, which includes groups such as procolophonids, millerettids, protorothyrids, and pareiasaurs. All anapsid skulls lack a temporal opening, while all other extant amniotes have temporal openings (although in mammals the hole has become the zygomatic arch). The millerettids, protorothyrids, and pareiasaurs became extinct in the late Permian period, and the procolophonoids during the Triassic.

However, it was later suggested that the anapsid-like turtle skull may be due to reversion rather than to anapsid descent. More recent morphological phylogenetic studies with this in mind placed turtles firmly within diapsids, slightly closer to Squamata than to Archosauria. All molecular studies have strongly upheld the placement of turtles within diapsids; some place turtles within Archosauria, or, more commonly, as a sister group to extant archosaurs. Reanalysis of prior phylogenies suggests that they classified turtles as anapsids both because they assumed this classification (most of them studying what sort of anapsid turtles are) and because they did not sample fossil and extant taxa broadly enough for constructing the cladogram. It has been suggested that *Testudines* diverged from other diapsids between 200 and 279 million years ago, though the debate is far from settled.

The earliest known fully-shelled turtle is the late-Triassic *Proganochelys*. The genus species already had many advanced turtle traits, and thus probably had many millions of years of preceding turtle evolution and species in its ancestry. It did lack the ability to pull its head into its shell (and it had a long neck), and had a long, spiked tail ending in a club, a body form similar to that of ankylosaurs resulting from convergent evolution.

Turtles are divided into two extant suborders, the Cryptodira and the Pleurodira. The Cryptodira is the larger of the two groups and includes all the marine turtles, the terrestrial tortoises, and many of the freshwater turtles. The Pleurodira are sometimes known as the side-necked turtles, a reference to the way they withdraw their heads into their shells. This smaller group consists primarily of various freshwater turtles.



A chart of the two extant Testudine suborders. Extinct groups that existed within these two suborders are shown as well.

Turtle genera with basal or uncertain phylogenetic position

- Genus †*Australochelys* (Chelonia *incertae sedis*)
- Genus †*Murrhardtia* (Chelonia *incertae sedis*)
- Genus †*Palaeochersis* (Chelonia *incertae sedis*)
- Genus †*Chinlechelys* (Proganochelydia or basal Testudines)
- Genus †*Chelycarapookus* (Testudines *incertae sedis*)
- Genus †*Chitracephalus* (Testudines *incertae sedis*)
- Genus †*Neusticemys* (Testudines *incertae sedis*)
- Genus †*Scutemys* (Testudines *incertae sedis*)

Chapter- 6

Reptile Anatomy

Crocodilian armor

The **crocodile exoskeleton** consists of the protective dermal and epidermal components of the integumentary system in animals of the order Crocodilia. It is a form of armour.

Structure and anatomy

The epidermal exoskeleton of the alligator consists of oblong horney scales, arranged in transverse rows; the long axes of the scales are parallel to that of the body. On the tail, except along the mid-dorsal line, and on the ventral side of the trunk and head these scales are very regular in outline and arrangement; on the sides of the head and trunk and on the legs they are much smaller and less regularly arranged, while along the mid-dorsal line of the tail, especially in its posterior half, they are elevated into tall keels that give the tail a large surface area for swimming. The first three digits of both manus (fore foot) and pes (hind foot) are armed with horny claws, which also belong to the epidermal part of the exoskeleton.

The dermal exoskeleton consists of bony scutes that underlie the epidermal scales of the dorsal surface of the trunk and anterior part of the tail. The overlying scales, except in very young animals, are always rubbed off, so that the bony scales are exposed. The ventral or inner surface of the scutes is flat, while the outer surface is strongly keeled and in old animals is often rough and pitted. The plates are nearly square in outline and are closely joined together in most places.

The scutes are grouped in two fairly distinct areas known as the nuchal and the dorsal shields. The former lies just back of the head, in the region of the fore legs, and consists of four larger and a number of smaller plates. The latter, or dorsal shield, extends over the back in fairly regular longitudinal rows and quite regular transverse rows. At the widest part of the trunk there are six or eight of these scutes in one transverse row. They become smaller towards the tail.

The teeth are exoskeletal structures, partly of ectodermal, partly of dermal origin. They are conical in shape, without roots, and are replaced when lost. They will be described in connection with the skull.

Musk glands, said by Gadow to be present in all Crocodilia, are found in both sexes and are derivations of the skin. One pair, each of which may be as large as a walnut, is found on the lower side of the head, one on the inside of each half of the mandible. The other pair is inside of the lips of the cloaca.

Histology of the integument

The epidermis of an embryo, young, or half-grown Crocodilia contains the *rete Malpighii*: a single layer of short, cylindrical cells. Over the rete are somewhat flattened, disk-shaped cells formed by transverse division of the underlying rete cells. On the outside lies the *epitrichial layer*, a mosaic of polygonal cells each with an oval nucleus near its middle. Between the epitrichial cells are small oval holes, not unlike the stomata in the epidermis of plant tissues. Bronn thinks these are not artifacts, but he does not suggest any explanation of their occurrence.

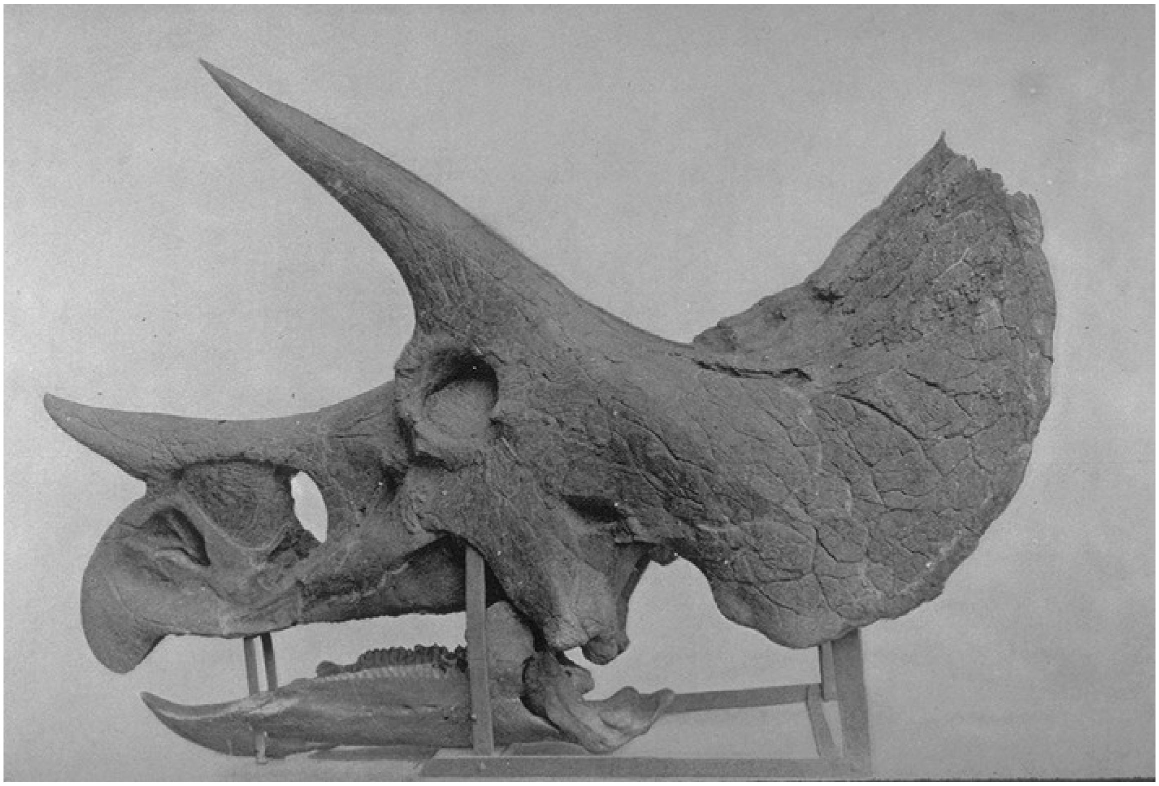
On the short, cylindrical rete Malpighii cells are flattened cells that gradually become very flat and lose their nuclei as they pass over into the horny layer. The stratum corneum consists of strongly flattened cells in which the nuclei can no longer be clearly seen, though their location can usually be determined by the groups of pigment granules. On the cells of the more superficial layers of the stratum corneum are straight, dark lines, perhaps ridges caused by pressure of the over- or underlying polygonal cells. The individual cells of the horny layer are usually easily isolated in the belly and neck regions where they never become very thick; but in the back the cells in this layer are very numerous and fuse with each other to form the bony plates; here the rete is the only clearly differentiated layer. Whether prickle cells are present in the epidermis of the crocodile Bronn is not certain, though he thinks they probably are.

Rathke pointed out that on the surface of certain folds of the integument, especially in the region of the jaws, are found in all Crocodilia certain small, scattered, wart-like elevations, around each of which is customarily a narrow, shallow, circular groove; they usually have a dark brown but sometimes a gray or even white color. Microscopic examination shows these warts to be of epidermal origin, consisting of bright, round cells that are closely united, without visible intercellular substance. Treatment with potassium hydroxide and then with water will show sometimes, though not always, fine granular nuclei in the cells. In probably all members of the genus Crocodilus, at least is found, on the thick swelling on the right and on the left side of the neck and trunk, a small, flat pit which has the appearance of the opening of an integumental gland. The pits are present also in the scales of the throat, under the side of the neck, sides of the body, lateral and ventral surfaces of the anterior half of the tail, and the legs. They are near the hinder border of the scales. Only occasionally are two pits found in one scale. These pits are found in the gavials but are absent in some, probably all, alligators. A small knob projects from the center of some of the pits. These pits are not openings of glands but have about the same structure as the pits seen in the head.

The integumental bones in the Crocodilia originate in the connective tissue of the cutis. Investigations in young animals show that these bones usually take their origin in the under and middle layers of the cutis and generally work towards the periphery.

Neck frill

Frill-necked lizard showing its neck frills.



Skull of *Triceratops* with its large neck frill.

Neck frill is the popular term for the relatively extensive margin seen on the back of the heads of reptiles with either a bony support such as those present on the skulls of dinosaurs of the suborder Marginocephalia or a cartilaginous one as in the Frill-necked Lizard. In technical terms, the bone-supported frill is composed of an enlarged parietal bone flanked by elongated squamosals and sometimes ringed by epoccipitals, bony knobs that gave the margin a jagged appearance. In the early 1900s, the parietal bone was known among paleontologists as the dermosupraoccipital. In some genera, such as *Triceratops*, *Pentaceratops* and *Torosaurus*, this extension is very large. Despite the neck frill predominantly being made of hard bone, some neck frills are made of skin, as is the case with the Frill-necked Lizard of today that resides in Australia.

The use of the neck frill in dinosaurs is relatively unknown; it may have been used for thermoregulation or simply as a defense mechanism. Indeed, during battles for territory, competing *Triceratops* crashed heads together with their elongated horns and the neck frill may have been employed as a kind of shield, protecting the rest of the animal from harm. However, usage of the neck frill in modern reptiles is better documented. Two chief and disparate examples are the Horned Lizards (genus *Phrynosoma*) with a bony frill, and the Frill-necked Lizard (Genus *Chlamydosaurus*) with a cartilaginous frill. The Frill-necked Lizard's frill is mainly made up of flaps of skin, which are usually coloured pink, supported by cartilaginous spines. Similar to the portrayal of the dinosaur *Dilophosaurus* in Steven Spielberg's *Jurassic Park*, the Frill-necked Lizard can puff out these neck frills either side of its head when threatened. The lizards often raise their frills when battling for territory or when making themselves seem bigger when threatened. There is however, no evidence that suggests that *Dilophosaurus* had the same abilities, as many of its features in the Jurassic Park film were purely fictional.

Numerous other animals of both modern and prehistoric times use both skin or bone protrusions to make themselves seem more threatening, attract mates or to thermoregulate. Examples of these are the usage of dewlaps and crests in lizards, dinosaurs and birds.

Chapter- 7

Marine Reptiles

Mesosaur

Mesosaurs Temporal range: Cisuralian, 299–280 Ma	
 *Mesosaurus*	
Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Subclass:	Anapsida
Order:	**†Mesosauria** Seeley, 1892
Family:	**†Mesosauridae** Baur, 1889

Genera
†*Brasileosaurus*? †*Stereosternum* †*Mesosaurus*

Mesosaur ("middle lizards") were an order of small aquatic reptiles that lived during the early Permian period, roughly 299 to 280 million years ago. Mesosaurs were the first aquatic reptiles, having returned to a watery way of life after evolving on land.

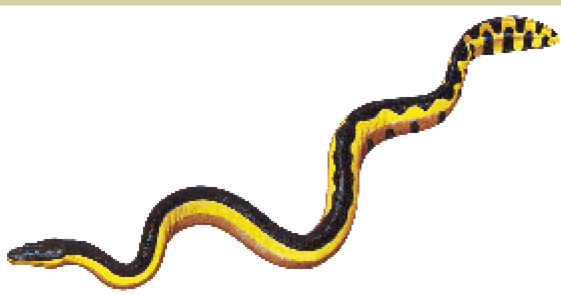
Mesosaurus

The best-known mesosaur is *Mesosaurus* itself. Fossils of the animal were found in Namibia, Africa and parts of South America, such as Brazil, Uruguay, Argentina and Paraguay. The widespread distribution of the fossil - particularly in those areas of Africa and South America which, when viewed on a map of the Earth, appear to 'interlock' - helped to reinforce the idea of continental drift.

Mesosaurus vaguely resembled a small alligator, although the most common specimens are only 40 centimetres (16 in) in length. Nonetheless, the largest specimen is almost 2 metres (6.6 ft) in length, and *Mesosaurus* was probably the largest marine reptile of its time. It is believed to have fed on fish, or possibly crustaceans, by using its teeth as a sieve, rather like modern-day whales.

Sea snake

Sea snake



Yellow-bellied sea snake, *Pelamis platurus*

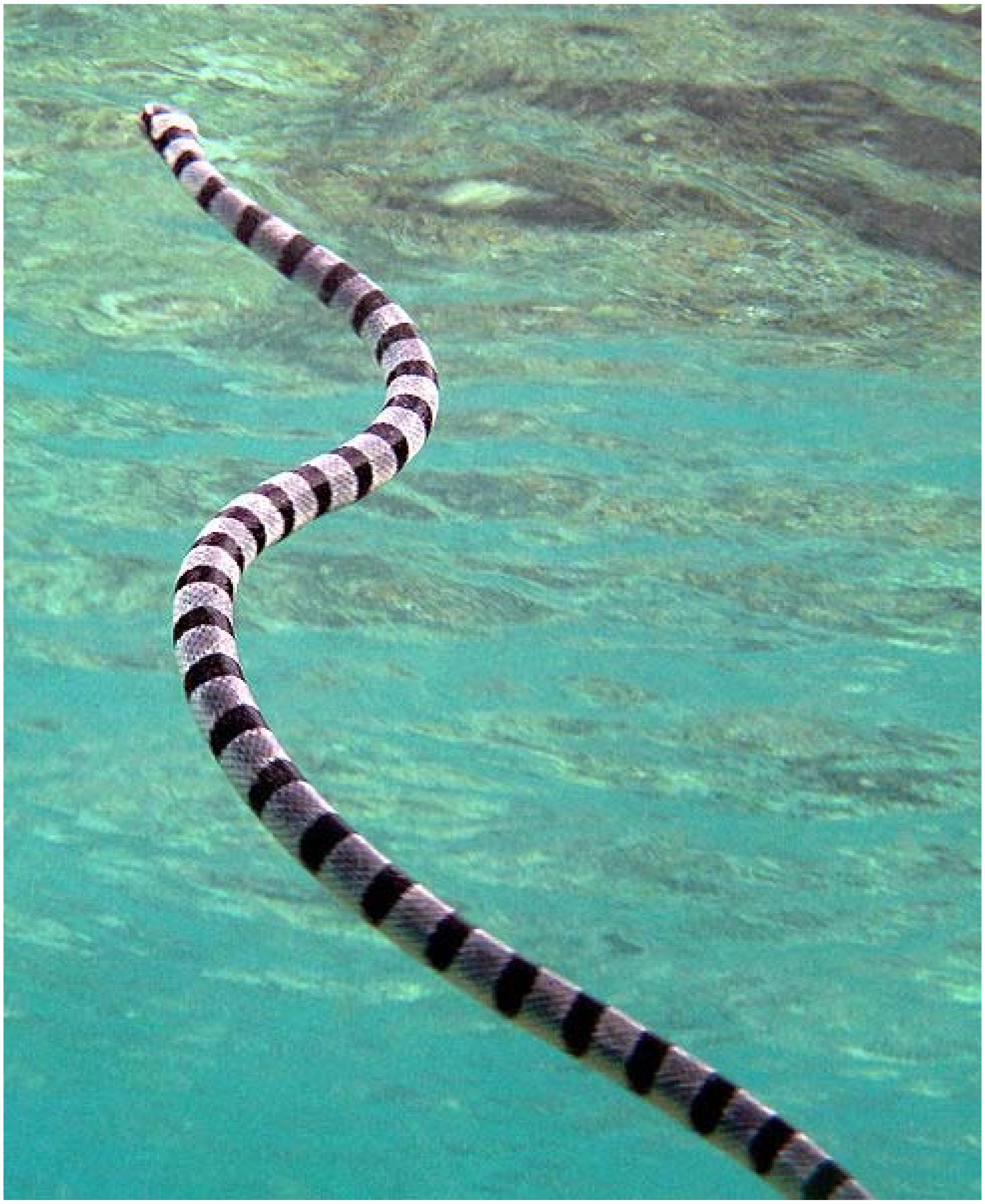
Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Reptilia
Order:	Squamata
Suborder:	Serpentes
Family:	**Hydrophiidae**

Boie, 1827

Sea snakes are venomous elapid snakes that inhabit marine environments for most or all of their lives. Though they evolved from terrestrial ancestors, most are extensively adapted to a fully aquatic life and are unable to even move on land, except for the genus *Laticauda*, which retain ancestral characteristics which allow limited land movement. They are found in warm coastal waters from the Indian Ocean to the Pacific. All have paddle-like tails and many have laterally compressed bodies that give them an eel-like appearance. Unlike fish, they do not have gills and must surface regularly to breathe. They are among the most completely aquatic of all air-breathing vertebrates. Among this group are species with some of the most potent venoms of all snakes. Some have gentle dispositions and bite only when provoked, but others are much more aggressive. Currently, 17 genera are described as sea snakes, comprising 62 species.

Description

Adults of most species grow to between 120–150 cm (3.9–4.9 ft) in length, with the largest, *Hydrophis spiralis*, reaching a maximum of 3 m (9.8 ft). Their eyes are relatively small with a round pupil and most have nostrils that are located dorsally. The skulls do not differ significantly from terrestrial elapids, although the dentition is relatively primitive with short fangs and (with the exception of *Emydocephalus*) as many as 18 smaller teeth behind them on the maxilla.



Yellow-lipped sea krait, *Laticauda colubrina*.

Most sea snakes are completely aquatic and have adapted to their environment in many ways, the most characteristic of which is a paddle-like tail that has increased their swimming ability. To a varying degree, the bodies of many species are laterally compressed, especially in the pelagic species. This has often caused the ventral scales to become reduced in size, even difficult to distinguish from the adjoining scales. Their lack of ventral scales means that they have become virtually helpless on land, but as they live out their entire life cycle at sea, they have no need to leave the water.

The only genus that has retained the enlarged ventral scales is the sea kraits, *Laticauda*, with only five species. These snakes are considered to be more primitive, as they still spend much of their time on land, where their ventral scales afford them the necessary grip. *Laticauda* are also the only sea snakes with internasal scales, i.e., their nostrils are not located dorsally.

As it is easier for a snake's tongue to fulfill its olfactory function under water, its action is short compared to that of terrestrial snake species. Only the forked tips protrude from the mouth through a divided notch in the middle of the rostral scale. The nostrils have valves consisting of a specialized spongy tissue to exclude water, and the windpipe can be drawn up to where the short nasal passage opens into the roof of the mouth. This an important adaptation for an animal that must surface to breathe, but may have its head partially submerged when doing so. The lung has become very large and extends almost the entire length of the body, although it is thought that the rear portion developed to aid buoyancy rather than to exchange gas. It is also possible that the extended lung serves to store air for dives.

Most sea snakes are able to respire through their skin. This is unusual for reptiles, because their skin is thick and scaly, but experiments with the black-and-yellow sea snake, *Pelamis platurus* (a pelagic species), have shown that this species can satisfy about 20% of its oxygen requirements in this manner, which allows for prolonged dives.

Blue-lipped sea krait, *Laticauda laticaudata*.

Like other land animals that have adapted to life in a marine environment, sea snakes ingest considerably more salt than their terrestrial relatives through their diet and when sea water is inadvertently swallowed. This meant that they had to evolve a more effective means of regulating the salt concentration of their blood. Mammals have the advantage of being able to pass salt in solution, mostly in the urine, but kidney function in birds and reptiles is too weak to remove salt in sufficient amounts. In birds, such as penguins, salt is removed through nasal glands, just as with the marine iguanas of the Galapagos Islands. Sea turtles have lacrimal glands that allow them to produce very salty tears. In sea snakes, the posterior sublingual glands, located under and around the tongue sheath, evolved to allow them to expel salt with their tongue action.

Scalation among sea snakes is highly variable. As opposed to terrestrial snake species that have imbricate scales to protect against abrasion, the scales of most pelagic sea snakes do not overlap. Reef dwelling species, such as *Aypisurus*, do have imbricate scales to protect against the sharp coral. The scales themselves may be smooth, keeled, spiny or granular, the latter often looking like warts. *Pelamis* has body scales that are "peg-like", while those on its tail are juxtaposed hexagonal plates.

Aipysurus laevis has been found to have photoreceptors in the skin of its tail, allowing it to detect light and presumably aiding it to remain hidden inside coral holes during the day. While other species have not been tested, it is possible that *A. laevis* is not unique among sea snakes in this respect.

Distribution and habitat

Sea snakes are mostly confined to the warm tropical waters of the Indian Ocean and the western Pacific Ocean, with a few species found well out into Oceania. The geographic range of one species, *Pelamis platurus*, is wider than that of any other reptile species, save for a few species of sea turtles. It extends from the east coast of Africa, from Djibouti in the north to Cape Town in the south, across the Indian Ocean, the Pacific, south as far as the northern coast of New Zealand, all the way to the western coast of the Americas, where it occurs from northern Peru in the south (including the Galápagos Islands) to the Gulf of California in the north. Isolated specimens have been found as far north as San Clemente in the United States.

Sea snakes do not occur in the Atlantic Ocean. It is thought that *Pelamis* would be found there were it not for the cold currents off Namibia and western South Africa that keep it from crossing into the eastern South Atlantic, or south of 5° latitude along the South American west coast. Sea snakes do not occur in the Red Sea*, believed to be due to its increased salinity, so there is no danger of them crossing through the Suez Canal. Salinity, or rather a lack thereof, is also thought to be the reason why *Pelamis* has not crossed into the Caribbean via the Panama Canal.

Despite their marine adaptations, most sea snakes prefer shallow waters near land, around islands, and especially waters that are somewhat sheltered, as well as near estuaries. They may swim up rivers and have been reported as far as 160 km (99 mi) from the sea. Others, such as *Pelamis platurus*, are pelagic and are found in drift lines; slicks of floating debris brought together by surface currents. Some sea snakes inhabit mangrove swamps and similar brackish water habitats and there are two landlocked fresh water forms: *Hydrophis semperi* occurs in Lake Taal in the Philippines, and *Laticauda crockeri* in Lake Te Nggano on Rennell Island in the Solomon Islands.

Behavior

Stidworthy (1974) describes all sea snake species as being reluctant to bite, and Fichter (1982) adds that they are quite docile. Spawls and Branch (1994) also claims they are mainly non-aggressive. The US Navy describes sea snakes as generally mild tempered, although there is variation among species and individuals. Mehrtens (1987) suggests that species such as *Pelamis platurus*, that feed by simply gulping down their prey, are more likely to bite when provoked because they seem to use their venom more for defence. This is in contrast to others, such as *Laticauda*, that use their venom for prey immobilization; these snakes are frequently handled with impunity by local fishermen. Species that have been reported as much more aggressive include *Aipysurus laevis*, *Astrotia stokesii*, *Enhydrina schistosa* and *Hydrophis ornatus*.

Olive sea snake, *Aipysurus laevis*.

Ditmars (1933) mentions that when they are taken out of the water, their movements become very erratic. They crawl awkwardly in these situations and can become quite aggressive, striking wildly at anything that moves. Yet they are frequently caught in nets by fishermen, who unravel and throw them back barehanded, usually suffering no harm. On land, sea snakes are unable to coil and strike like terrestrial snakes.

Observations suggest that sea snakes are active both day and night. In the morning, and sometimes late in the afternoon, they can be seen at the surface basking in the sunlight. When disturbed, they dive below. Sea snakes have been reported swimming at depths of over 90 m (300 ft). They can remain submerged for as long as a few hours, possibly depending on temperature and degree of activity.

Huge aggregations of sea snakes have been reported. For example, in 1932 millions of *Astrotia stokesii*, a relative of *Pelamis*, were seen from a steamer in the Strait of Malacca, off the coast of Malaysia, and formed a line of snakes 3 m (9.8 ft) wide and 100 km (62 mi) long. The cause of this phenomenon is unknown, although it likely has to do with reproduction. Ditmars (1933) mentions that, in that same area, sea snakes can sometimes be seen swimming in schools of several dozen, and that after typhoons many dead specimens can be found on the beaches.

Feeding

Most sea snake species prey on fish, especially eels. The latter, when bitten, stiffen and die within seconds. One species prefers molluscs and crustaceans, such as prawns, while a few others feed only on fish eggs, which is unusual for a venomous snake. Some reef dwelling species have small heads and thin necks, making it possible for them to extract small eels from the soft bottom where they hide. Stidworthy (1974) states that sea snakes will sometimes take bait from a fishing line.

Reproduction

Except for a single genus, all sea snakes are ovoviviparous; the young are born alive in the water where they live their entire life cycle. In some species, the young are quite large: up to half as long as the mother. The one exception is the genus *Laticauda*, which is oviparous; its five species all lay their eggs on land.

Venom

Like their cousins in the Elapidae family, the majority of sea snakes are highly venomous; however, when bites occur, it is rare for much venom to be injected, so that envenomation symptoms usually seem non-existent or trivial. For example, *Pelamis platurus* has a venom more potent than any other terrestrial snake species in Costa Rica, but despite its abundance in the waters off its western coast, few human fatalities have been reported. Nevertheless, all sea snakes should be handled with great caution.

Bites in which envenomation does occur are usually painless and may not even be noticed when contact is made. Teeth may remain in the wound. There is usually little or no swelling, and it is rare for any nearby lymph nodes to be affected. The most important symptoms are rhabdomyolysis (rapid breakdown of skeletal muscle tissue) and paralysis. Early symptoms include headache, a thick-feeling tongue, thirst, sweating, and vomiting. Symptoms that can occur after 30 minutes to several hours post-bite include generalized aching, stiffness, and tenderness of muscles all over the body. Passive stretching of the muscles is also painful, and trismus, which is similar to tetanus, is common. This is followed later on by symptoms typical of other elapid envenomations: a progressive flaccid paralysis, starting with ptosis and paralysis of voluntary muscles. Paralysis of muscles involved in swallowing and respiration can be fatal. After 3–8 hours, myoglobin as a result of muscle breakdown may start to show up in the blood plasma, which can cause the urine to turn a dark reddish, brown, or black color, and eventually lead to acute renal failure. After 6 to 12 hours, severe hyperkalemia, also the result of muscle breakdown, can lead to cardiac arrest.

Taxonomy

Sea snakes were at first regarded as a unified and separate family, the Hydrophiidae, that later came to comprise two subfamilies: the Hydrophiinae, or true/aquatic sea snakes (now 16 genera with 57 species), and the more primitive Laticaudinae, or sea kraits (1 genus, *Laticauda*, with 5 species). Eventually, as it became clear just how closely related the sea snakes are to the elapids, the taxonomic situation became less well-defined. Some taxonomists responded by moving the sea snakes to the Elapidae, thereby creating the subfamilies Elapinae, Hydrophiinae and Laticaudinae, although the latter may be omitted if *Laticauda* is included in the Hydrophiinae. No one has yet been able to convincingly work out the phylogenetic relationships between the various elapid subgroups, and the situation is still unclear. Therefore, others opted to either continue to work with the older traditional arrangements, if only for practical reasons, or to lump all of the genera together in the Elapidae, with no taxonomic subdivisions, to reflect the work that remains to be done.

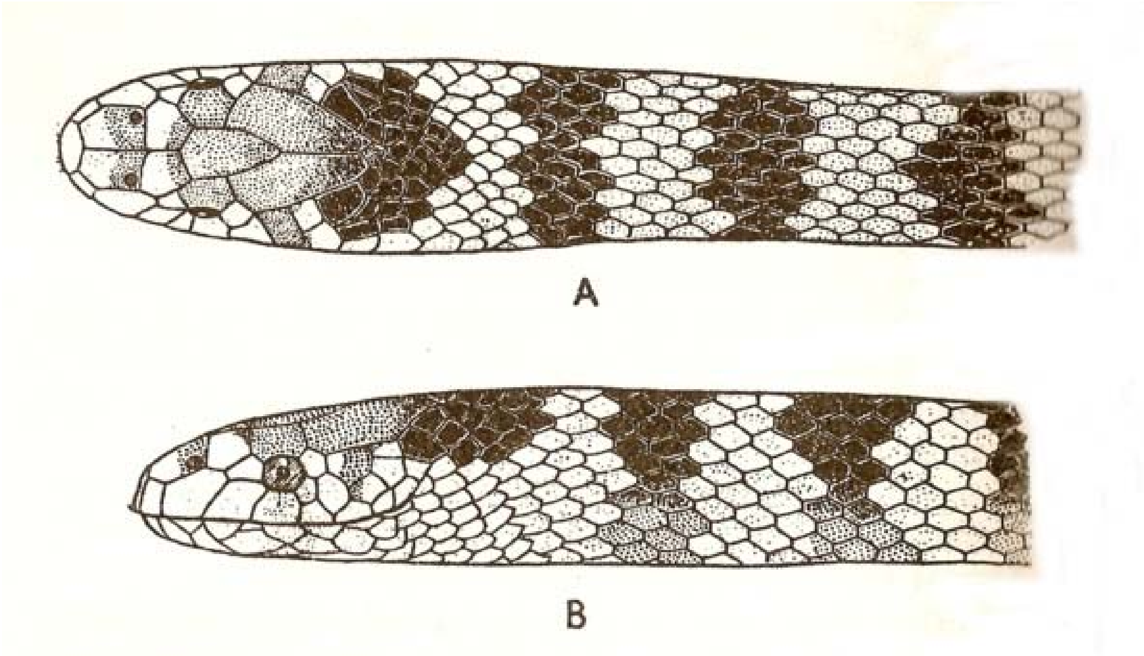
Genus	Taxon author	Species	Subsp.*	Common name	Geographic range
Acalyptophis	Boulenger, 1869	1	0	Spiny-headed Sea Snake or Horned Sea Snake	Gulf of Thailand, South China Sea, the Strait of Taiwan, and the coasts of Guangdong, Indonesia, Philippines, New Guinea, New Caledonia, Australia (Northern Territory, Queensland, Western Australia)
Aipysurus	Lacépède, 1804	7	1	Olive sea snakes	Timor Sea, South China Sea, Gulf of Thailand, and coasts of Australia (North Territory, Queensland, West Australia), New Caledonia, Loyalty

					Islands, southern New Guinea, Indonesia, western Malaysia and Vietnam.
Astrotia	Fischer, 1855	1	0	Stoke's sea snake	Coastal areas from west India and Sri Lanka through Gulf of Thailand to China Sea, west Malaysia, Indonesia east to New Guinea, north and east coasts of Australia, Philippines
Emydocephalus	Krefft, 1869	2	0	Turtlehead sea snakes	The coasts of Timor (Indonesian sea), New Caledonia, Australia (North Territory, Queensland, West Australia), and in the Southeast Asian Sea along the coasts of China, Taiwan, Japan, and the Ryukyu Island.
Enhydrina	Gray, 1849	2	0	Beaked sea snakes	In the Persian Gulf (Oman, United Arab Emirates, etc.), south to the Seychelles and Madagascar, SE Asian Sea (Pakistan, India, Bangladesh, Myanmar, Thailand, Vietnam), Australia (North Territory, Queensland), New Guinea and Papua New Guinea.
Ephalophis	M.A. Smith, 1931	1	0	Grey's mudsnake	North-western Australia
Hydrelaps	Boulenger, 1896	1	0	Port Darwin mudsnake	Northern Australia, southern New Guinea
Hydrophis	Latreille *In* Sonnini & Latreille, 1801	34	3	Sea snakes	Indoaustralian and Southeast Asian waters.
Kerilia	Gray, 1849	1	0	Jerdon's sea snake	Southeast Asian waters.
Kolpophis	M.A.	1	0	Bighead	Indian Ocean.

	Smith, 1926			sea snake	
Lapemis	Gray, 1835	2	0	Spine-bellied Sea Snake, Shaw's Sea Snake	Persian Gulf to Indian Ocean, South China Sea, Indo-Australian archipelago and the western Pacific.
Laticauda	Laurenti, 1768	5	0	Sea kraits	Southeast Asian and Indoaustralian waters.
Parahydrophis	Burger & Natsuno, 1974	1	0	Northern mangrove sea snake	Northern Australia, southern New Guinea
Parapistocalamus	Roux, 1934	1	0	Hediger's snake	Bougainville Island, Solomons
Pelamis	Daudin, 1803	1	0	Yellow bellied sea snake	Indian and Pacific Oceans
Praescutata	Wall, 1921	1	0		From the Persian Gulf to the Indian Ocean, the South Chinese Sea, and northeast to the coastal region of Fujian and Strait of Taiwan.
Thalassophis	P. Schmidt, 1852	1	0	Anomalous sea snake	South Chinese Sea (Malaysia, Gulf of Thailand), Indian Ocean (Sumatra, Java, Borneo)

**) Not including the nominate subspecies.*

Captivity



Hydrophis cyanocinctus

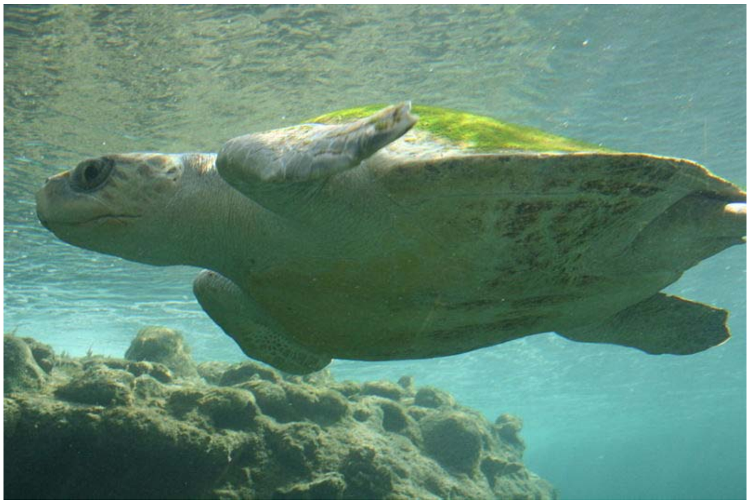
At best, these snakes make difficult captives. Ditmars (1933) described them as nervous and delicate captives that usually refuse to eat, preferring only to hide in the darkest corner of the tank. Over 50 years later, Mehrtens (1987) wrote that although they were rarely displayed in western zoological parks, some species were regularly on display in Japanese aquariums. Available food supply is one factor that limits the number of species that can be kept in captivity, since some have diets that are too specialized. Another is that some species appear too intolerant to handling, or even being removed from the water. Regarding their facilities, the *Laticauda* species need to be able to exit the water somewhere and bask, while the other strictly aquatic genera do not, basically requiring only a tank of filtered (synthetic) sea water maintained at about 29°C, along with a submerged shelter. Species that have done relatively well in captivity include the ringed sea snake, *Hydrophis cyanocinctus*, which feed on fish and eels in particular. *Pelamis platurus* has done especially well in captivity, accepting small fish, including goldfish. However, care has to be taken to house them in round or oval tanks, or in rectangular tanks with corners that are well-rounded, to prevent the snakes from damaging their snouts by swimming into the sides.

Conservation status

Most sea snakes are not on the CITES protection lists. Only one species, *Laticauda crockeri*, is classified as vulnerable (VU) according to the IUCN Red List of Threatened Species.

Sea turtle

Sea turtles	



An olive ridley sea turtle

Conservation status

Endangered (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Testudines
Suborder:	Cryptodira
Superfamily:	**Chelonioidea** Bauer, 1893

Genera

- Family **Cheloniidae** (Oppel, 1811)
  - *Caretta*
  - *Chelonia*
  - *Eretmochelys*
  - *Lepidochelys*
  - *Natator*
- Family Dermochelyidae
  - *Dermochelys*
- Family Protostegidae (extinct)
- Family Toxochelyidae (extinct)

- Family Thalassemyidae (extinct)

Sea turtles (superfamily **Chelonioidea**) are marine reptiles that inhabit all of the world's oceans except the Arctic.

Distribution

The superfamily Chelonioidea has a world-wide distribution; sea turtles can be found in all oceans except for the polar regions. Some species travel between oceans. The flatback sea turtle is found solely on the northern coast of Australia.

Biology

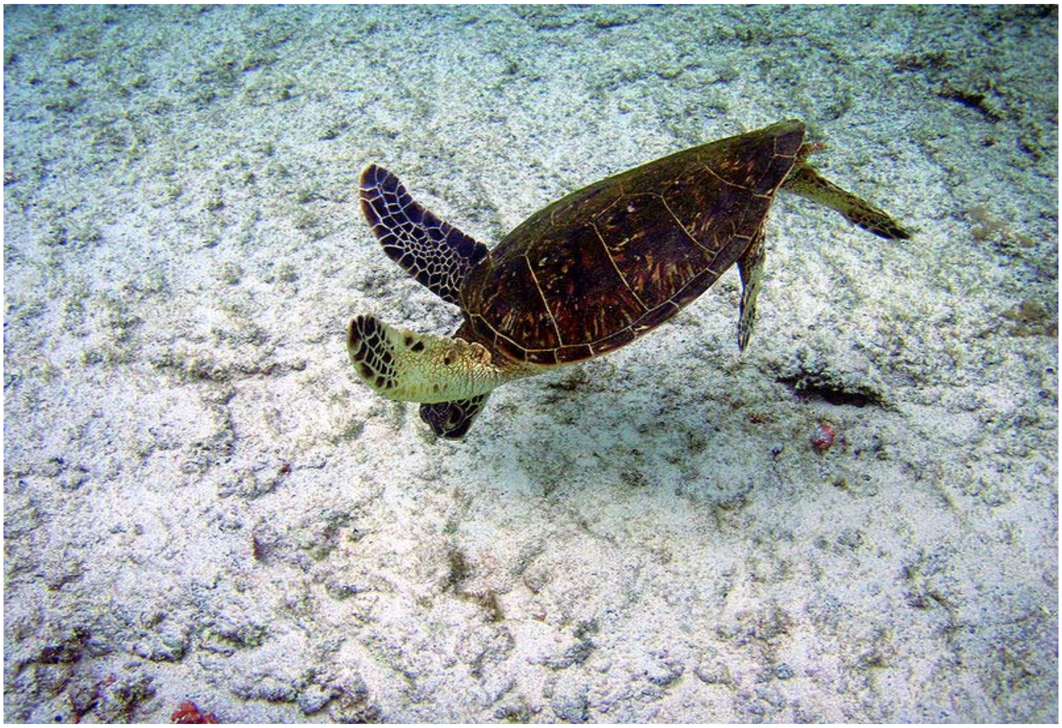
Respiration

A Green sea turtle breaks the surface to breathe.

Sea turtles are almost always submerged in water, and, therefore, have developed an anaerobic system of respiration. Although all sea turtles breathe air, under dire circumstances they may divert to anaerobic respiration for long periods of time. When surfacing to breathe, a sea turtle can quickly refill its lungs with a single explosive exhalation and rapid inhalation. Their large lungs have adapted to permit rapid exchange of oxygen and to avoid trapping gases during deep dives. However, sea turtles must emerge while breeding, given the extra level of activity.

Life history

Hawksbill sea turtle swims at Black Hills, Honduras



A feeding green sea turtle, *Chelonia mydas*

According to SeaWorld Parks & Entertainment, a lifespan of 80 years is feasible for sea turtles.

It takes decades for sea turtles to reach sexual maturity. After mating at sea, adult female sea turtles return to land to nest at night. Different species of sea turtles exhibit various levels of philopatry. In the extreme case, females return to the beach where they hatched. This can take place every two to four years in maturity. They make from one to eight nests per season.

The mature nesting female hauls herself onto the beach, nearly always at night, and finds suitable sand on which to create a nest. Using her hind flippers, she digs a circular hole 40 to 50 centimetres (16 to 20 in) deep. After the hole is dug, the female then starts filling the nest with a clutch of soft-shelled eggs one by one until she has deposited around 50 to 200 eggs, depending on the species. Some species have been reported to lay 250 eggs, such as the hawksbill. After laying, she re-fills the nest with sand, re-sculpting and smoothing the surface until it is relatively undetectable visually. The whole process takes thirty to sixty minutes. She then returns to the ocean, leaving the eggs untended.

The hatchling's gender depends on the sand temperature. Lighter sands maintain higher temperatures, which decreases incubation time and results in more female hatchlings.

Incubation takes about two months. The eggs in one nest hatch together over a very short period of time. When ready, hatchlings tear their shells apart with their snout and dig through the sand. Again, this usually takes place at night, when predators such as seagulls cannot fly. Once they reach the surface, they instinctively head towards the sea. If, as happens on rare occasions, hatching takes place during daylight, only a very small proportion of each hatch (usually 0.01%) succeed, because local opportunist predators, such as the common seagull, gorge on the new sea turtles. Thus there is an obvious evolutionary drive to hatch at night, when survival rates on the beach are much higher.

The hatchlings then proceed into the ocean, where a variety of marine predators await them. In 1987, Carr discovered that the young of *Chelonia mydas* and *Caretta caretta* spent a great deal of their pelagic lives in floating sargassum beds, where there are thick mats of unanchored seaweed. Within these beds, they found ample shelter and food. In the absence of sargassum beds, sea turtle young feed in the vicinity of upwelling "fronts". In 2007, Reich determined that green sea turtle hatchlings spend the first three to five years of their lives in pelagic waters. In the open ocean, pre-juveniles of this particular species were found to feed on zooplankton and smaller nekton before they are recruited into inshore seagrass meadows as obligate herbivores.

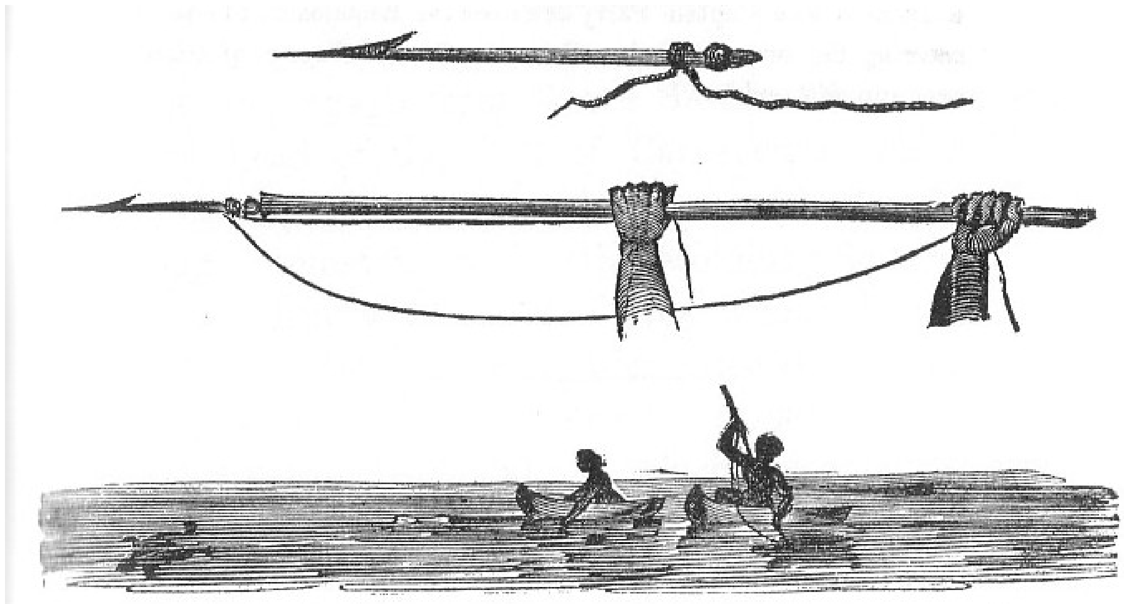
Instead of nesting individually like the other species, Ridley sea turtles come ashore en masse, known as an "arribada" (arrival). With the Kemp's ridley sea turtles this occurs during the day.

Salt gland

Sea turtles possess a salt excretory gland at the corner of the eye, in the nostrils, or in the tongue, depending on the species; chelonian salt glands are found in the corner of the eyes in leatherback sea turtles. Due to the iso-osmotic makeup of jellyfish and the other gelatinous prey upon which sea turtles subsist, sea turtle diets are high in salt; chelonian salt gland excretions are almost entirely composed of sodium chloride 1500-1800 mosmoll-1 (Marshall and Cooper, 1988; Nicolson and Lutz, 1989; Reina and Cooper, 2000).

Importance to humans

Moche Sea Turtle. 200 A.D. Larco Museum Collection, Lima, Peru



"Manner in which Natives of the East Coast strike turtle". Near Cooktown, Australia. From Phillip Parker King's Survey. 1818.

Marine sea turtles are caught worldwide, although it is illegal to hunt most species in many countries. A great deal of intentional marine sea turtle harvests worldwide are for food.

Many parts of the world have long considered sea turtles to be fine dining. Ancient Chinese texts dating to the fifth century B.C. describe sea turtles as exotic delicacies. Many coastal communities around the world depend on sea turtles as a source of protein, often harvesting several sea turtles at once and keeping them alive on their backs until needed. Coastal peoples gather sea turtle eggs for consumption.

Sea turtles are popular in Mexico as boot material and food.

To a much lesser extent, specific species of marine sea turtles are targeted not for their flesh, but for their shells. Tortoiseshell, a traditional decorative ornamental material used in Japan and China, comes from the carapace scutes of the hawksbill sea turtle. Ancient Greeks and ancient Romans processed sea turtle scutes (primarily from the hawksbill) for various articles and ornaments used by their elites, such as combs and brushes. The skin of the flippers are prized for use as shoes and assorted leather goods.

The Moche people of ancient Peru worshipped the sea and its animals. They often depicted sea turtles in their art.

Sea turtles enjoy immunity from the sting of the deadly box jellyfish and regularly eat them, helping keep tropical beaches safe for humans.

Sea turtles, especially green sea turtles, are one of the few animals that eat sea grass. Sea grass needs to be constantly cut short to help it grow across the sea floor. Sea turtles act as grazing animals that cut the grass short and help maintain the health of the sea grass beds. Sea grass beds provide breeding and developmental grounds for numerous species of fish, shellfish and crustaceans. Without sea grass beds, many marine species humans harvest would be lost, as would the lower levels of the food chain. The reactions could result in many more marine species eventually becoming endangered or extinct.

Beaches and dune systems do not get many nutrients. Sea turtles use beaches and the lower dunes to nest and lay their eggs. Sea turtles lay around 100 eggs in a nest and lay between 3 and 7 nests during the summer nesting season. Along a 20-mile stretch of beach on the east coast of Florida sea turtles lay over 150,000 lbs of eggs in the sand. Dune vegetation is able to grow and become stronger with the presence of nutrients from sea turtle eggs, unhatched nests, eggs and trapped hatchlings. As the dune vegetation grows stronger and healthier, the health of the entire beach/dune ecosystem becomes better. Stronger vegetation and root systems helps to hold the sand in the dunes and helps protect the beach from erosion.

Beach towns, such as Tortuguero, Costa Rica, have transitioned from a tourism industry that made profits from selling sea turtle meat and shells to an ecotourism-based economy. Tortuguero is considered to be the founding location of sea turtle conservation. In the 1960s the cultural demand for sea turtle meat, shells, and eggs were quickly killing once abundant sea turtle populations that nested on the beach. The Caribbean Conservation Corporation began working with villagers to promote ecotourism as a permanent substitute to sea turtle hunting. Sea turtle nesting grounds became sustainable. Since the creation of a sea turtle, ecotourism-based economy, Tortugero annually houses thousands of tourists who visit the protected 22-mile beach that hosts sea turtle walks and nesting grounds.

Conservation

All species of sea turtles are listed as threatened or endangered. The leatherback, Kemp's Ridley, and hawksbill sea turtles are critically endangered. The Olive Ridley and green sea turtles are endangered, and the loggerhead is threatened. The flatback's conservation status is unclear due to lack of data.

One of the most significant threats now comes from bycatch due to imprecise fishing methods. Long-lining has been identified as a major cause of accidental sea turtle death. There is also black-market demand for tortoiseshell for both decoration and supposed health benefits.

Sea turtles must surface to breathe. Caught in a fisherman's net, they are unable to surface and thus suffocate. In early 2007, almost a thousand sea turtles were killed inadvertently in the Bay of Bengal over the course of a few months after netting.

However, some relatively inexpensive changes to fishing techniques, such as slightly larger hooks and traps from which sea turtles can escape, can dramatically cut the mortality rate. Turtle Excluder Devices (TEDs) have reduced sea turtle bycatch in shrimp nets by 97 percent. Another danger comes from marine debris, especially from abandoned fishing nets in which they can become entangled.

Beach development is another area which threatens sea turtles. Since many sea turtles return to the same beach each time to nest, development can disrupt the cycle. There has been a movement to protect these areas, in some cases by special police. In some areas, such as the east coast of Florida, conservationists dig up sea turtle eggs and relocate them to fenced nurseries to protect them from beach traffic.

Since hatchlings find their way to the ocean by crawling towards the brightest horizon, they can become disoriented on developed stretches of coastline. Lighting restrictions can prevent lights from shining on the beach and confusing hatchlings. Sea turtle-safe lighting uses red or amber LED light, invisible to sea turtles, in place of white light.

Another major threat to sea turtles is black-market trade in eggs and meat. This is a problem throughout the world, but especially a concern in the Philippines, India, Indonesia and the coastal nations of Latin America. Estimates reach as high as 35,000 sea turtles killed a year in Mexico and the same number in Nicaragua. Conservationists in Mexico and the United States have launched "Don't Eat Sea Turtle" campaigns in order to reduce this trade in sea turtle products. These campaigns have involved figures such as Dorismar, Los Tigres del Norte and Maná. Sea turtles are often consumed during the Catholic season of Lent, even though they are reptiles, not fish. Consequently, conservation organizations have written letters to the Pope asking that he declare sea turtles meat.

Loggerhead sea turtle exits from fishing net through a turtle excluder device (TED)

Climate change may also cause a threat to sea turtles. Since sand temperature at nesting beaches defines the sex of a sea turtle while developing in the egg, there is concern that rising temperatures may produce too many females. However, more research is needed to understand how climate change might affect sea turtle gender distribution and what other possible threats it may pose.

Fibropapillomatosis disease causes tumors in sea turtles.

Injured sea turtles are sometimes rescued and rehabilitated by professional organizations, such as the Mote Marine Laboratory in Sarasota, Florida, the Marine Mammal Center in Northern California, the ClearWater Marine Aquarium in Clearwater, Florida, and the Sea Turtle Inc. organization in South Padre Island, Texas. One such sea turtle, named Nickel for the coin that was found lodged in her throat, lives at the Shedd Aquarium in Chicago.

In the Caribbean, researchers are having some success in assisting a comeback. In September 2007, Corpus Christi, Texas, wildlife officials found 128 Kemp's ridley sea turtle nests on Texas beaches, a record number, including 81 on North Padre Island (Padre Island National Seashore) and four on Mustang Island. Wildlife officials released 10,594 Kemp's ridleys hatchlings along the Texas coast this year.

Also in 2007, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service issued a determination that the leatherback, the hawksbill and the Kemp's Ridley populations were endangered while that of green sea turtles and olive ridleys were threatened.

In Southeast Asia, the Philippines has had several initiatives dealing with the issue of sea turtle conservation. In 2007, the province of Batangas in the Philippines declared the catching and eating of Pawikans illegal. However, the law seems to have had little effect as Pawikan eggs are still in demand in Batangan markets. In September 2007, several Chinese poachers were apprehended off the Turtle Islands in the country's southernmost province of Tawi-Tawi. The poachers had collected more than a hundred sea turtles, along with 10,000 sea turtle eggs.

Sea turtles are very vulnerable to oil pollution, both because of their tendency to linger on the water's surface, and because oil can effect them at every stage of their life cycle. Oil can poison the sea turtles upon entering their digestive system,

Fragile ecosystems

Sea turtles on a beach in Hawaii

Sea turtles play key roles in two ecosystem types that are critical to them as well as to humans—oceans and beaches/dunes. In the oceans, for example, sea turtles, especially green sea turtles, are one of very few creatures (manatees are another) that eat the sea grass that grows on the sea floor. Sea grass must be kept short to remain healthy, and beds of healthy sea grass are essential breeding and development areas for many species of fish and other marine life. A decline or loss of sea grass beds would damage these populations, triggering a chain reaction and negatively impacting marine and human life.

Beaches and dunes form a fragile ecosystem that depends on vegetation to protect against erosion. Eggs, hatched or unhatched, and hatchlings that fail to make it into the ocean are nutrient sources for dune vegetation. Every year, sea turtles lay countless eggs on beaches. Along one twenty-mile (32 km) stretch of beach in Florida alone, for example, more than 150,000 pounds of eggs are laid each year.

Taxonomy and evolution

Immature Hawaiian Green sea turtle in shallow waters

Eurysternum wagneri fossil at the Museum für Naturkunde, Berlin

Sea turtles, along with other turtles and tortoises, are part of the order Testudines.

The seven living species of sea turtles are: flatback sea turtle, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle and olive ridley sea turtle. All species except the leatherback are in the family Cheloniidae. The leatherback belongs to the family Dermochelyidae and is its only member.

The species are primarily distinguished by their anatomy: for instance, the prefrontal scales on the head, the number of and shape of scutes on the carapace, and the type of inframarginal scutes on the plastron. The leatherback is the only sea turtle that does not have a hard shell; instead, it bears a mosaic of bony plates beneath its leathery skin. It is the largest sea turtle, measuring 6 to 7 feet (1.8 to 2.1 m) in length at maturity, and 3 to 5 feet (0.91 to 1.5 m) in width, weighing up to 1,300 pounds (590 kg). Other species are smaller, being mostly 2 to 4 feet (0.61 to 1.2 m) and proportionally narrower.

Sea turtles constitute a single radiation that became distinct from all other turtles at least 110 million years ago.

From *SWOT Report*, vol. 1:

- **Family Cheloniida**
    - *Chelonia mydas* or green sea turtle

    - *Eretmochelys imbricata* or hawksbill sea turtle
    - *Natator depressus* or flatback sea turtle
    - *Caretta caretta* or Loggerhead sea turtle
    - *Lepidochelys kempii* or Kemp's ridley sea turtle
    - *Lepidochelys olivacea* or olive ridley sea turtle
- **Family Dermochelyidae**
    - *Dermochelys coriacea* or leatherback sea turtle

Below is a cladogram showing the phylogenetic relationships of living and extinct sea turtles in the family Cheloniidae based on Lynch and Parham (2003) and Parham and Pyenson (2010). In a wider sense (*sensu lato*), Cheloniidae includes many extinct species dating back to the Late Cretaceous. In the strictest sense (*sensu stricto*), Cheloniidae includes only living sea turtles and a few more recently extinct species. The leatherback sea turtle is placed within Cheloniidae in the tribe Carretini, along with the Ridley sea turtles.

Chapter- 8

Extinct Reptiles

Culebra Island Giant Anole

Culebra Island Giant Anole

Conservation status

Critically Endangered (IUCN 2.3)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata

Class:	Reptilia
Order:	Squamata
Suborder:	Iguania
Family:	Polychrotidae
Genus:	*Anolis*
Species:	**A. roosevelti**
Binomial name	
Anolis roosevelti (Grant, 1931)	
Synonyms	
Xiphosurus roosevelti	

The **Culebra Island Giant Anole** (*Anolis roosevelti*, *Xiphosurus roosevelti* (according to ITIS)) is an extremely rare or possibly extinct lizard of the *Anolis* genus. It is native to Culebra Island in Puerto Rico.

Description

The Culebra Island Giant Anole was first described in 1931 by American zoologist Chapman Grant. It is named in honor of Theodore Roosevelt, Jr., who was the governor of Puerto Rico to that time. It is endemic to Culebra, where it lives in forested zones on the slopes of Mt. Resaca.

It can reach a length of 160 mm. The color of the body is brown-grey, while the tail has a yellow-brown hue and the abdomen is whitish. The throat fan varies from gray on the upperparts to yellow on the underparts, and the eyelids are yellow. A further feature are two long drawn-out lines on both sides of the body; one starts at the ears, the other at the shoulder.

Threats

Though it was only observed again in 1932 after its discovery there are unconfirmed sightings since 1973 (the last one in 1978). Some experts believe that it might still exist. It preferred a habitat with gumbo-limbo and ficus trees because it fed from the fruits of the trees. Due to human activities the habitat was almost destroyed; only a few specimens of the Culebra Giant Anole can be seen in museums. It was listed as federally endangered in the Endangered Species Act in 1977.

Kawekaweau

Delcourt's gecko	
Conservation status	

Extinct (IUCN 2.3)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Squamata
Suborder:	Lacertilia
Family:	Gekkonidae
Subfamily:	Diplodactylinae
Genus:	*Hoplodactylus*
Species:	***H. delcourti***
Binomial name	
Hoplodactylus delcourti	

The **Kawekaweau**, *Hoplodactylus delcourti*, was by far the largest of all geckos with a snout to vent length of 370 mm and an overall length of at least 600 mm. It was endemic to New Zealand and is now believed to be extinct. This would make Leach's giant gecko of New Caledonia, at 360mm in total length, the largest surviving species of gecko in the world - this leaves the endangered Duvaucel's gecko as the largest surviving species of gecko in New Zealand and *one of the largest* in the world. This animal's specific epithet is after the surname of French museum worker Alain Delcourt - he was the person who discovered the forgotten specimen in the basement of the Marseille museum.

In 1870 a Māori chief killed a Kawekaweau he found under the bark of a dead rata tree in the forests of the Waimana Valley, which are now protected as part of the northern section of Te Urewera National Park. This is the only documented report of anyone ever seeing one of these animals alive. He described it as being "brownish with reddish stripes and as thick as a man's wrist". A single stuffed museum specimen was "discovered" in the basement of the Natural History Museum of Marseille in 1986, but unfortunately the origins and date of collection of the specimen remain a total mystery, as when it was found, it was unlabelled. However, scientists examining it eventually came to the conclusion that it was from New Zealand and was in fact the lost "Kawekaweau", a giant and mysterious forest lizard of Maori oral tradition.

Leiolopisma mauritiana

Leiolopisma mauritiana	
Conservation status	

Extinct (IUCN 2.3)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia (paraphyletic)
(unranked):	Sauria
Order:	Squamata (paraphyletic)
Infraorder:	Scincomorpha
Family:	Scincidae
Subfamily:	Lygosominae
Genus:	*Leiolopisma*
Species:	*L. mauritiana*

Binomial name

Leiolopisma mauritiana
Günther, 1877

Synonyms

Didosaurus mauritianus

Leiolopisma mauritiana also known as "*Didosaurus maurtianus*," was a large (the largest known)species of skink (family Scincidae). It was found only in Mauritius, but became extinct around 1600 probably due to introduced predators. It may have been somewhat fossorial in nature. This is speculative and based on a reconstruction. The Mauritianus giant skink is known from an incomplete skeleton. Didosaurus mauritianus (underlined), the Mauritian Giant Skink, became extinct by 1650. Only a semi - complete specimen is known in addition to some odd bones. (Supposedly, a former director of the Mauritian Institute threw away specimens including some bones of Didosaurus). The remaining skeleton is missing the feet and digits, thus making it impossible for a SENI biometric analysis per se {Schnirel. 2004}. The semi - complete skeleton does have a skull shaped similar to a blue-tongue skink (Genus: Tiliqua). The restoration undertaken by the (Species in Bronze Project), if accurate, gives a SENI value of .06 which would indicate that Didosaurus could have been fossorial or saxicolous in lifestyle. This is further linked by the fact that the closest living relative of Didosaurus (as mentioned by the restorers) is the Round Island Skink: Leiolopisma telfeirii (underlined). The Round

Island Skink also gives a SENI value of .06. The Round Island Skink is a species capable of caudal autotomy. This skink is often seen darting in the underbrush or between rocks.

An undescribed extinct *Leiolopisma* from Réunion was closely related, whereas the Round Island skink is a more distantly related surviving species from Mauritius.(Austin & Arnold 2006)

Martinique Curly-tailed Lizard

Martinique Curly-tailed Lizard	
Conservation status	

Extinct (IUCN 2.3)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Squamata
Family:	Leiocephalidae
Genus:	*Leiocephalus*
Species:	***L. herminieri***
Binomial name	
Leiocephalus herminieri (Duméril & Bibron, 1837)	

The **Martinique Curly-tailed Lizard** (*Leiocephalus herminieri*) is an extinct lizard from the family of curly-tailed lizards (Leiocephalidae). The Latin name commedorates the French naturalist Félix Louis L'Herminier. There are five museum specimens of which three are deposed in Paris, one in London and a further in Leiden. Though Martinique is assumed as range of this species there was some confusion about the type locality in the past. While André Marie Constant Duméril and Gabriel Bibron stated Martinique and Trinidad and Tobago as type locality George Albert Boulenger has given only Trinidad and Tobago as terra typica. Biology, the reasons for its extinction and the date of extinction are unknown. This species was last collected in the 1830s.

Of the three specimens from Paris the largest female is measured with 139 mm and the largest male with 126 mm. The large head scales are more or less distinctly striate. The large dorsal scales are keeled and forming continuous oblique series. The smaller lateral and ventral scales are keeled too. The back is greenish brown with less or more irregular yellowish crossbands. The head is yellowish with four or five black bars on the sides. The venter is yellowish. The throat has oblique black transverse bands.

Rodrigues day gecko

Rodrigues day gecko

Scientific classification	
Kingdom:	Animalia

Phylum:	Chordata
Class:	Reptilia
Order:	Squamata
Family:	Gekkonidae
Subfamily:	Gekkoninae
Genus:	*Phelsuma*
Species:	***P. edwardnewtoni***
Binomial name	
Phelsuma edwardnewtoni (Boulenger, 1884)	

Rodrigues day gecko (***Phelsuma edwardnewtoni***) is a now extinct diurnal species of geckos. It lived on the island of Rodrigues and typically inhabited forests and dwelt in trees. The Rodrigues day gecko fed on insects and nectar.

Scientific synonyms

- *Phelsuma edwardnewtoni* VINSON & VINSON 1969
- *Phelsuma newtoni* BOULENGER 1884
- *Phelsuma edwardnewtoni* - KLUGE 1993
- *Phelsuma edwardnewtoni* - RÖSLER 2000: 101

Description

This day gecko is now extinct. It was described also as *P. newtonii*, yet this name was also used as a synonym for *Phelsuma gigas*. *P. edwardnewtoni* belonged to the largest day geckos. It reached a total length of about 23 cm. Earlier investigators describe the animal as being quite common. However, this species has not been sighted since 1917, in spite of thorough searches in the 1960s and 1970s on Rodrigues and all offshore islets. Today, only 5 preserved specimens remain, three of which are in The Natural History Museum in London, the two others being in the Paris Museum. These specimens have been preserved in alcohol and show a thick-bodied, robust Phelsuma. The body colour has been described as bright green with bright blue spots on the back. The underside of the tail was whitish yellow. The chin had a deep yellow colour.

Distribution

This species inhabited Rodrigues Island and its surrounding islets.

Habitat

P. edwardnewtoni has been observed on coconut trees and other palms. Their habitat has been largely destroyed by humans and introduced animals such as cats and rats, which may have been the main cause of their extinction.

Diet

These day geckos fed on various insects and other invertebrates. They also liked to lick soft, sweet fruit, pollen and nectar.

Behaviour

P. edwardnewtoni was documented as being unafraid of humans. It was quite tame and would even eat fruit from one's hand.