Chapter 2
Reptiles

It is not the strongest of the species nor the most intelligent that survives.
It is the one that is the most adaptable to change.

(C. Darwin)

Abstract Reptiles started their long evolutionary process in the mid-Carboniferous. Numerous adaptations allowed reptiles to colonize new environments, something that amphibians were not able to do, with very few exceptions, because they are tied to water for reproduction. After the appearance of the Amnios, reptiles underwent other evolutions, perfecting and adapting to new needs, for example, the evolution of the skulls, Anapsid, Diapsid, and Synapsid.

Keywords Biology of snake · Reptiles · Amnion · Captorinomorfi · Reptiles skull · Anapsid · Diapsid · Synapsid

The word "reptile" derives from the Latin verb *"reptare"*, which means "to crawl", which is perhaps a snake's most obvious characteristic. The reptile classification includes all vertebrate, amniotic, and ectothermic organisms whose skin is covered with scales.

The reptile is in a Class of Vertebrates that has about 7,000 species. Of these, 2,900 (Uetz 1999) are snakes, making it the most species-rich suborder after lizards. For further information on the systematics of snakes see Table 2.1.

Reptiles are divided into four orders:

1. **Testudines** (Turtles)
2. **Squamata** (Snakes, lizards, and amphisbaenians)
3. **Crocodilia** (Crocodiles)
4. **Sphenodontia** (Tuataras)

The appearance of the *amnios* gave reptiles the opportunity to develop the entire ontogeny, from egg to adult, within the multifaceted subaerial environment. This has allowed reptiles to conquer a massive adaptive radiation that has characterized

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Table 2.1 Systematic classification of snakes

Systematic classification	
Kingdom	*Animalia*
Subkingdom	*Eumetazoa*
Superphylum	*Deutrostomia*
Phylum	*Chordata*
Subphylum	*Vertebrata*
Superclass	*Tetrapoda*
Clade	*Amniota*
Class	*Reptilia* (Laurenti 1768)
Order	*Squamata*
Suborder	*Serpentes*

the evolution of this *taxon* during Mesozoic times. The group that gave rise to the *Amniota taxon* is the *Anthracosauria* (Zug et al. 2001). *Amnios* and waterproof skin are the main characteristics that distinguish reptiles from amphibians. The ability to reproduce far away from water has greatly benefited reptiles in comparison to amphibians, which still need water in order to breed and lay their eggs or larvae (with the exception of *Plethodontidae*, or lungless salamanders). This is one of the reasons why amphibians are amongst the animals most at risk of extinction; they are the most affected by human interactions. The simple act of spreading salt on roads to prevent freezing can affect frogs and toads.

The long evolutionary history of reptiles started at least 310 million years ago, in the mid-Carboniferous period, as confirmed by the discovery in Canada (Nova Scotia) of a fossil attributed to the Captorhinidae family, *Hylonomus*, a lizard-like reptile. These animals are a group that started the evolution of all other reptiles, with the exception of turtles (Cogger and Zweifel 1993). But it is during the Mesozoic era (240–65 million years ago), that reptiles had their maximum expansion and dominance of the land as well as the water.

The classification of reptiles is based on the morphology of the skulls, which reflect different levels of evolution. Through these studies, it was possible to split reptiles into five subclasses.

The first skull in evolutionary order is the anapsid. The anapsids' skulls were found in the first reptiles (captorinomorfi) and now only present in testudines (turtles and tortoises who only have one orbital hole in their skulls). Through successive evolutionary steps, reptiles evolved and their skulls started to have openings in the posterolateral wall, called temple fenestra, where the cranial muscles are attached. Anapsids were followed by synapsids and consequently diapsids (two temple fenestrae or two arches). These are divided in Archosauromorpha and Lepidosauromorpha. The second group, which appeared in the Permian age, includes snakes, lizards, amphisbaenians, and sphenodontia. When specifically looking at snakes, it would be more accurate to define their skulls as modified diapsids. The modification consists of an adaptation related to the lifestyles of snakes. Their temporal fossa disappeared to allow the square bone to have better cranial kinesis. The diapsids' temporal hole strengthen the cranial muscles,

Fig. 2.1 X-ray of an aglyphous cranium of a *Morelia harrisoni.* Note the morphology of the quadrate bone that allows greater adherence to highly developed muscle tissue (X-ray performed at the Veterinary Clinic of Matelica, University of Camerino)

and in snakes, this function is performed by the unique geometry of the quadrate bone. Looking closely at the quadrate bone of a snake, we can find three keels that increase the bone surface for muscle adhesion (Fig. 2.1).

From an anatomical point of view, reptiles share similarities with birds. As a matter of fact, the discovery of *Archaeopteryx* confirmed that reptiles originated from birds. *Archaeopteryx* is a small dinosaur that was found in Solnhofer in Germany. This finding has become famous in zoology because it is the proof that reptiles and birds are linked. The *Archeopteryx* (*Archaeopteryx lithographica*) is considered the most advanced of the dinosaurs and the most primitive of birds. The lack of a beak does, however, classify this reptile among the dinosaurs. The findings were taken from rocks from the Upper Jurassic times (about 150 million years ago) in Bavaria. The generic name derives from the Greek and means "ancient wing". The first traces were found in 1860, one year after the publication of Charles Darwin's book, *The Origin of species*. These findings were, essentially, a confirmation of Darwin's theory, because the intermediate characters of the skeleton combine typical structures of both reptiles and birds, making *Archeopteryx* the link that connects reptiles and birds. The most distinctive of the animal's anatomical features are its feathers, perfectly preserved in fine-grained limestone deposits from Franconia. The skeleton and especially the head are still decidedly reptilian, as are the lack of a beak and its well-defined teeth. Even today this phyletic relationship is visible by comparing the embryonic buds of scales and feathers, which appear as morphologically identical counterparts.

As for snakes, their origin is controversial. Some scholars argue that their ancestors are Varanidae reptiles that became legless because they were forced to adapt to living in sediments, while others argue they derive from mosasaurs (Bellairs and Underwood 1951). If so, the origin of snakes would stem from aquatic environments, as is confirmed by the fossilized remains of serpents with limbs, attributable to different genres (*Eupodophis*, *Haasiophis*, *Mesophis*, *Pachyophis* and *Pachyrhachis*) (Caldweel 2007; Caldweel and Lee et al. 1997).

Serpents are the link in the evolutionary chain after lizards, and represent the last group of reptiles that appeared on Earth from 180 to approximately 135 million years ago, during Jurassic times. The fossilized remains of the oldest serpent were found in strata belonging to the era of low-Cretaceous, dating back to 120 million years ago (Rage and Richter 1994). Other authors (Marais 2004) cite dates between 100 and 150 million years ago. According to Szyndlar and Rage (1999) the first viper to invade the European continent was attributable to the *complex Vipera aspis*, as confirmed by vertebrae fossils dating back to the Miocene. Dolnice attributes these remains to *Vipera antiqua* (Szyndlar and Böhme 1993).

Some lizards can be mistakenly identified as snakes, such as *Chalcides chalcides* and *Anguis fragilis*. These two species could be examples of adaptive convergence toward snakes. Despite having tiny or even absent legs, such as slow worms (limbless), these reptiles cannot be considered snakes, since they retain the typical characteristics of the suborder of lizards: movable eyelids, tympanic hole, and tail regeneration. The latter is a defence strategy that the animals use when needed. With a strong contraction of the muscles, the animal can drop its tail. The tail regrows after the animal sheds its skin a number of times. In dropping its tail, the lizard hopes to escape by distracting a predator that is intent on biting off its tail. The new tail grows back after a few months. Even if the color and the size of the new appendage will not be as bright as the original one, it is still just as functional. The name *fragilis* derives from the ease with which these lizards drop their tails.

As we know, reptiles are "cold blooded", but the correct term to define them is "ectothermic". These animals have a metabolism that is dependent upon the temperature of the environment in which they live, or even on the thermoregulation opportunities presented by abiotic factors. In contrast, homeothermic animals (like birds and mammals) maintain a constant body temperature, regardless of whether the outside temperature is cold or hot. Homeotherms pay for this "luxury" by having to feed daily with large amounts of food, and maintain high levels of oxygenation of the blood by means of constant breathing and complex lung morphology. If temperatures were to fall, mammals are capable of burning brown fat, which allows them to convert heat energy reserves in order to prevent hypothermia.

For reptiles and all other ectothermic animals, the need for thermoregulation via energy sources (sun, water, fermenting organic matter) is a specific characteristic. Due to normal seasonal patterns, reptiles have time spans of activity that alternate with periods of inactivity (hibernation). If we consider that these animals' vitality peaks between 25 and 30 °C, we can immediately understand why they spend hours and hours in the sun, and, after having stored the heat, they move to cooler areas. Sometimes snakes can increase the surface area of their sun exposure by stretching out their ribs and flattening themselves to the ground (common in *Vipera ursinii* and *Vipera berus*).

All reptiles have indefinite growth. Once they reach a certain size (different from species to species) they will slowly but surely continue to grow and shed their skins. A young snake sheds its skin about every four meals (over approximately a month), while an adult will rarely shed more than three times a year. The shedding period is stressful for reptiles, and lasts about a dozen days. During this time span, snakes do not normally eat (although there are exceptions), their movements are limited, and they look for a quiet and humid place to retreat. The search for wetlands is essential for reptiles in order to be able to form the interstitial fluid between the two layers of skin (old and new) and properly separate. The appearance of the interstitial fluid causes opalescence on the skin and on the eyelids. Not surprisingly, if a wet skin is found, it is a sign that the animal has just shed it a few minutes prior and the snake itself is probably still in the area. It may be right next to its old skin, or perhaps under a rock. Why do snakes lie under rocks? Virtually all of the world's snakes can be defined as thigmotropic animals. They feel the need to hide under certain conditions. For snakes, feeling safe does not mean hiding in a cave, but in a narrow crevice that is hardly able to contain them. A snake feels safe when the burrow is completely filled up by its body, as if it were its own made-to-measure den. The snake contracts and inflates its muscles in order to be able to fit inside its hiding place.

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