# Reptile and Amphibian Intelligence: How Smart Are They?

Perhaps one of the most commonly asked questions that arises when it comes to reptiles and amphibians, collectively referred to as herptiles, whether in the wild, in captivity, or both, is a measure of these animal's levels of intelligence and cognitive abilities. Do they like to be petted and/or handled? Are they able to recognize their owners/keepers or other certain individuals? Can they, or do they form special bonds or relationships with us as humans or learn who we are? Do they want to, or like being in a cage or enclosure? Can they be trained in any way? These are all common questions asked by the general public and reptile enthusiasts alike at many various venues and while through conducting educational outreach. While we must be careful as not to anthropomorphize, or attribute human qualities and emotions to these animals, certainly, many reptiles and amphibians can indeed be quite intelligent and perceptive animals, oftentimes much more so than traditionally believed. This has been observed, at least anecdotally, and is often spoken of by many pet owners, keepers, breeders, field herpers, naturalists and others who maintain these animals in captivity and/or set out to find and observe them in the wild. But surely there are more scientific accounts and specific examples of how and what these animals can learn?

Indeed, there are! Traditionally, little has been thought of when it came to the intelligence of these animals in particular, and the widespread, and oftentimes negative public perceptions and fears many have, or have had certainly do not help. "Instinctual", "Primitive", "Simple Minded", and other negative perceptions have all been adjectives used and widely believed to be the case of the reptilian and amphibian brains. However, these beliefs are quickly beginning to change and become challenged as growing bodies of new findings, discoveries, and evidence have been uncovered in recent decades. Now known as "cold-blooded cognition", many of these new findings have the strong potential of changing how we view cognitive evolution, these animals in particular, and what remains to be learned from studying these amazing animals.

So how have these findings gone undetected and understudied for so long until now? The answer likely lays with early cognitive studies and research conducted on reptiles and amphibians as far back as the 1950's and 1960's, which had several critical design flaws. Perhaps the largest, and most noticeable flaw may have been that during these previous decades, much of the emphasis and design cognitive studies had were on mammals and birds, rather than other non-avian herptiles. This, therefore may have been a design that set these maligned animals "up for failure" from the beginning. One such example which was used was "aversive stimuli", which used loud sounds and/or bright lights or other unpleasant stimuli to gauge an animal's reactions, specifically in rodents. However, these animals may often react very differently to the same stimuli by "freezing" or otherwise attempting to remain cryptic or engage in other defensive behaviors not considered in such studies.

Furthermore, the fact that these animals are ecothermic, rather than endothermic, has been another design flaw in such studies. It is believed that since herptiles and mammals divulged quite some time ago, approximately 280 million years or more, that sophisticated behaviors and learning in these animals could in fact be much older and more adaptive than previously believed, having evolved several times separately. Traditionally, the "triune brain theory" assumed that increasingly advanced behavior correlated with evolutionary advanced of different regions of the brain, most notably the cortex, or midbrain. The overall size of this region of the brain was thereby often associated with the amount of cognitive abilities and social behaviors. However, more recent research and findings have turned up surprising cognitive abilities in other, much more unlikely places of the brain, and that it may not actually be possible to pinpoint exact regions which may have traditionally been associated with higher or lower levels of consciousness and intelligence (7). It has been shown that red footed tortoises, and quite possibly other reptiles and amphibians lack a hippocampus, the area of the brain associated with learning, memory, and spatial navigation, but instead rely on an area of the brain known as the medial cortex, which is more often associated with more complex decision making and cognitive abilities (9).

Certainly, much more information about the vertebrate brain and its structure, anatomy, evolution, and physiology could be gone into much more detail when it comes to comparing and analyzing the evolutionary aspects of learning and intelligence in different animals in general. However, the recurring point remains the same in that when it comes to reptiles and amphibians, conventional "wisdom" and knowledge which may have been accepted decades ago is now coming under new review and revision. Certainty, when it comes to the many different scientific orders and families of reptiles and amphibians, many intriguing bodies of contemporary research and findings have, and can be made when it comes to each one. Amphibians, including frogs, toads, and even salamanders, as well as reptiles alike including turtles and tortoises, lizards, crocodilians, and even snakes have all been subject of new research, sometimes challenging what we may know, or in many cases, not know about these animals.

**Amphibians**

When it comes to herptiles, and even vertebrates in general, amphibians may have relatively simple brains, but this certainly does not mean that these particular animals are not capable of learning and displaying intelligence. In fact, among the amphibians, the anurans, or frogs and toads, are perhaps the most intelligent, and have the largest brain to body ratio of the amphibians. Many species of anurans and other amphibians have evolved fairly complex and innovative parental and reproductive behaviors in particular when it comes to rearing their eggs, tadpoles, or young. The African bullfrog, or Pixie frog (*Pyxicephalus adspersus*), one of the largest species of frogs in the world, for example, has developed a unique parental strategy where the male guards a small, shallow pool of eggs or tadpoles following laying by the female. When, or if the pond begins to dry up prematurely before the eggs hatch or tadpoles fully form, the male will then use his powerful fore and hind limbs to create a channel to the next nearest pool or body of water, thereby saving the young from dessication. Likewise, some species of frogs provide additional parental protection for their young by "swallowing" them and then regurgitating them when danger passes, or even carrying their eggs and tadpoles to the nearest pool of water, as in the case of dart frogs (family Dendrobatidae).

When it comes to the learning capacities of amphibians, both classical and operant conditioning, although only basic measures of intelligence and cognitive ability, have been observed and studied on numerous occasions. Certainly, as with many other herptiles and other animals, the fat and well fed frog or toad that locates an area with the most suitable amount of food and other resources, such as a backyard doorstep, or streetlight will often learn to return to these specific areas even after being relocated elsewhere numerous times. Another such study appearing in the 1965 book, Animal Behavior (Time, Inc.) by Niko Tinbergen, one of the foremost authors in animal ethology, conducted one such study on southern toads (Bufo/Anaxyrus terrestris) in Florida where the toads were presented with a series of edible and harmful/inedible insects (i.e. bees and wasps vs. harmless look-alike robber flies). After being stung initially by the bees, the toads subsequently refused both subsequent bees and the robber fly look-alikes, but continued to accept other food items which did not resemble bees, such as dragonflies. Unfortunately, the intelligence and learning abilities for other amphibians such as the caudates (or salamanders and newts), caecilians, and others, perhaps due to being less conspicuous and well-known amphibians in general, remains in need of further and closer study, although it would be unsurprising as well if findings were made demonstrating that these amphibians do in fact possess similar cognitive abilities as their anurans counterparts.

**<u>Chelonians (Turtles and Tortoises)</u>**

Among reptiles, the shelled reptiles widely known as chelonians, or turtles and tortoises have proven to be among the most intelligent and cognitive amongst these groups of animals with the track record of providing perhaps the first and earliest evidence of learning and imitation amongst reptiles. This is certainly no doubt due to the fact that chelonians, as well as most other reptiles, receive little to no parental care upon hatching or giving birth, and must develop and learn quickly in order to survive and become successful. In other words, there is a "strong natural selection for intelligence" in these animals (12). These quickly learned behaviors often greatly assist these animals in foraging and locating food efficiently, avoiding potential predators and threats, and in increasing their reproductive success. Both the North American wood turtle (*Glyptemys insculpta*) and eastern box turtles (*Terrapene carolina*), for example, has been observed to be quite intelligent in their foraging habits of tapping their fore limbs on the ground to potentially simulate rainfall or disturbances as a means of inducing earthworms and other invertebrates or other prey items to the surface of the soil for easier consumption by the turtles. Certainly, as with amphibians and many other reptiles, turtles and tortoises also possess very strong classical and operant conditioning, and other social or gregarious behaviors, especially amongst the aquatic to semi-aquatic pond turtles (family Emydidae) as well.

For further evidence of studies measuring reptilian intelligence, the simple, yet age old maze has been another long time laboratory test in which many species of turtles and tortoises have excelled at, oftentimes completing more quickly or successfully than their rodent counterparts. In one such notable example, a comparative animal psychologist at the University of London, England, Anna Wilkinson, tested a female red-footed tortoise (*Chelonoidis carbonaria*) in a series of radial arm maze tests, which were rewarded with a piece of strawberry at the end of each successful completion. In the study, it was found that the tortoise used external landmarks and strong navigational strategies and memory. The tortoise was also able to alter its behavior based on changing external circumstances and stimuli, which allows these animals to successfully take advantage of new environments and new food sources. Other, further studies have also shown tortoises to successfully imitate and learn from one another in such studies, and even learn and use touch screen technology to earn their rewards.

**<u>Lizards and Crocodilians</u>**

Lizards are an extremely large and diverse group of highly successful reptiles found throughout much of the world, and as with chelonians and other reptiles, have evolved and developed intelligence and high cognitive abilities to be able to quickly and successfully upon hatching or birth. Certainly, it can be easily seen how many of the larger, and highly versatile lizards including, but not limited to the teiid lizards such as tegus, whiptails, and racerunners, as well as iguanas, and varanids, or monitor lizards have quickly evolved to be highly intelligent animals. Among the herptiles, lizards perhaps comprise the largest bodies of cognitive research and studies, with many different learning functions and behaviors having been documented among the many different species, both great and small, and with some species perhaps being the most intelligent reptiles. Anoles, for example, *Anolis sp*., have been the research subjects of at least a few studies which utilized puzzles of varying levels of difficulty in which the lizards learned to problem solve by recognizing the switches and other mechanisms to open the containers consisting of their invertebrate prey. Other, similar studies with unfamiliar apparatus have been shown to be solved by juvenile black throated monitor lizards (Varanus albigularis) using live rodents contained inside of a transparent tube in which the lizards had to rotate the tubes in a certain way to open them (5).

Certainly, many more examples of social and cooperative behaviors have been documented amongst many different species of monitor lizards and other lizards in the wild as well. Many lizards utilize learned behaviors such as using their fore limbs to retrieve prey items from crevices or otherwise inaccessible locations, while other species of monitors have been shown to forage and hunt for larger or faster moving prey items cooperatively through planning ahead and arranging ambushes amongst members of the group. Many other lizards, such as green iguanas (*Iguana iguana*) have also been shown to exhibit very advanced social behaviors where, in the wild, males defend their areas of territory, as well as up to eight or more females in the same area by changing colors and performing other territorial displays intended to ward off rival males. Several other species of iguanas and some other species of lizards, furthermore, may nest communally, or otherwise will share nesting locations or complex burrow systems with up to dozens or even hundreds of other individuals of the same species.

Crocodilians, collectively consisting of the crocodiles, caimen, alligators, and other related species, are another group of quadruped reptiles that have been proven to be far more intelligent and complex animals than traditionally believed. Often widely thought of as just “mindless”, “predatory”, and “simple-minded” animals or “cold blooded killers”, crocodilians can in actuality be considered among the most intelligent reptiles, and have been shown to possess among the most intricate hunting, social, and reproductive strategies, even amongst animals in general. Females of many species of crocodilians construct large mounds near the water consisting of rotting vegetation and debris in which their eggs are laid and subsequently guarded closely by the female. Upon incubation and hatching, the female will then slowly and gently dig out the new hatchlings from the nest mound, and in the same set of jaws and teeth capable of exerting over 3,000 lbs. of pressure per square inch, will gently cradle and transport the young back to the water. When it comes to basking and thermoregulation, several species of crocodilians have also learned to adopt more arboreal, or tree dwelling behaviors than previously believed as a means of gaining better sun exposure while also learning that by doing so, a higher and better vantage point can be made for observing their surroundings (10). Finally, several more advanced and complicated forms of hunting behavior using sticks, twigs, and other vegetation and debris as additional cover and/or lures have been observed in several species of crocodilians as well (11). These are all only a select few of the advanced and complicated learning and cognitive abilities both many lizards and crocodilian species possess.

## **Snakes**

Perhaps no other group of reptiles or amphibians are as widely feared or revered throughout the world as are snakes. Many different public attitudes and cultural perceptions, both positive and negative alike surround snakes ever since early historical times. But, whether one loves these elongated, often limbless to nearly limbless reptiles or not, are they really just instinctual, “dumb snakes” as far as attitudes and perceptions towards them go? Well, as one could expect by now, this group of highly misunderstood reptiles have also been proven to be much more intelligent and perceptive than commonly believed. Certainly, some species of snakes which are active, diurnal hunters or predators, such as the North American racers, coachwhips, and whipsnakes (*Coluber sp*.), as well as perhaps one of the most widely known species of snakes, the king cobra (*Ophiophagus hannah*), a southeastern Asian to Philippine species, possess very high levels of intelligence, vision, and cognitive abilities, with the aforementioned king cobra being among the few snake species to construct and guard a nest consisting of a low mound of dead and decaying vegetation. At least one other snake species, the Cuban boa (Epicrates angulifer) has furthermore been recently shown to cooperative in loosely formed groups to capture smaller endothermic prey. Other bodies of scientific research and evidence when it comes to venomous snakes’ deliberate control of their venom delivery systems or apparatus in particular provide at least some additional evidence for cognitive thought and intelligence, as evidenced by the prevalence of dry bites in which no venom is released or injected (14).

When it came to mazes and other traditional tests of intelligence and cognition, snakes suffered one of the same setbacks as previously mentioned earlier which have plagued reptiles from the beginning in that such studies may in fact have not been designed well for these reptiles to begin with, and instead having favored rodents or other mammals. Instead, one researcher, Dr. David Holtzman of the University of Rochester modified these studies to better suit snakes as a means of determining their intelligence. Rather than a maze, a large, dark plastic tub was used with eight holes cut out at the bottom, with one leading to a hidden shelter underneath. In the study, twenty four corn snakes (*Pantherophis guttatus*) were taught using escape motivation to locate the correct holes using color cues and other stimuli (6). Surprisingly, younger snakes were able to more quickly locate the holes than older snakes, which may have relied more on sight. Of noteworthy mention was that snakes and other reptiles, unlike humans, possess an unrestricted ability to produce new brain cells throughout their lives. Certainly, the Jacobson's organ, or vomeronasal organ is also a well-known olfactory sensory mechanism in snakes and other squamate reptiles used to pick up chemical ques in their surroundings for interpretation. So while snakes may undoubtedly be capable of learning and intelligence, as with other reptiles and amphibians, the results of this particular study remain somewhat unclear, and unfortunately, few other studies, or efforts have yet been made to date determine to what extent snakes have the ability to learn. From a biological and evolutionary perspective at least, snakes would seem to be a relatively old, unchanged, and highly successful group of reptiles which may have relied or otherwise acted upon novel intelligence at least to a lesser degree than that of many other herptiles. Other notable scientific studies measuring snake intelligence include indigo snakes (*Drymarchon couperi*) learning to operate a relay for water through operant conditioning (https://rd.springer.com/article/10.3758/BF03332330), garter snakes (*Thamnophis sirtalis* and *Thamnophis radix*) being trained to follow and/or avoid lemon scents for food rewards (http://psycnet.apa.org/record/1988-28604-001), and wild Burmese pythons (*Python bivittatus*) being trained through operant conditioning to press buttons for food (https://rd.springer.com/article/10.1007/s10071-014-0797-1).

**Bonus Section-Arachnids and Other Invertebrates**

Although they may not be reptiles or amphibians, the keeping, study, and overall interest in other "creepy crawlies" including insects, arachnids, and other invertebrates often goes hand in hand with one another. In fact, the original intended meaning of the word "herpetology" was to include "every creeping thing". So how intelligent are invertebrates when it comes to learning and cognition? Do spiders have their smarts? Although the ganglias and overall nervous systems of the arthropod brain may appear to be more simple than that of many vertebrates, it is certainly widely known that many different invertebrates do have a tremendous array of different external and internal sensory organs, physiological, and mechanisms that are used to generate some of their behaviors. Mushroom bodies, or corpora pendunculata, are a pair of structures located in the brains of insects, arthropods, and some other invertebrates that play a role in their olfactory and memory. When compared to the vertebrate cerebral cortex, these mushroom bodies were considered to be the seat of intelligence in invertebrates (15). Further evidence of more complex social behaviors was also noted in the journal *Insectes Sociaux, which highlighted* the social behaviors of two so-called gregarious cockroach species, *Blattella germanica* and *Periplaneta americana*. Although not as sophisticated as eusocial insects such as ants or bees, it was indeed found that cockroaches can communicate, recognize kin, and even get "lonely" in isolation by using individually unique hydrocarbons and other chemical cues and markings (16).

And when it comes to spiders and other arachnids, although the prize for the smartest spider may not currently go to tarantulas or scorpions based on the amount of current evidence and research which have been conducted on them, several other species of spiders, including one genus of jumping spider, *Portia sp.,* known for cleverly hunting and luring other spiders, despite their tiny size, were found to plan out intricate detours to be able to reach prey, and showed further evidence of thought and cognition while in the lab (17). Furthermore, when it comes to arachnid intelligence, researchers at the Smithsonian found than in some species of spiders, the brains occupied as much as 80% of their body, and 25% of their legs (18). What can be said of spider intelligence in general is that these amazing arachnids do need relatively large and complex brains in general to form webs and perform other complex tasks associated with their hunting and overall survival. The general Haller's Rule for all animals was applied in this study, which generally states that brain size was proportional to body size of the animal.

## Summary and Conclusion

To summarize, the areas of intelligence, learning, and cognition when it comes to reptiles and amphibians is but just one of many areas that remain to be further studied and understood. "Cold blooded cognition" may still be in its early infancy, but from what it has taught us thus far has been that these animals are certainly by no means the "dumb", "inanimate" animals that many may have once believed them to be, and that the concepts of intelligence, learning, and cognition may in fact be much more widespread in the animal kingdom than previously believed. Popular theories and bodies of knowledge that social learning in many different animals is a byproduct of, and adaptation for group living are rapidly being turned on their ears as more findings continue to be made suggesting that learning and intelligence are instead a result of many more animal's than once believed general ability to learn and adapt to changing environments and circumstances, otherwise known as behavioral flexibility. This can even be shown in many species of insects, arachnids, and other invertebrates in which an interest in often go hand in hand with keeping and/or observing reptiles and amphibians. These ever newly developing findings have, and certainly will continue to further shape and even redefine how and what we may know and understand about these amazing animals, both in the wild and in captivity for many years, and generations to come.

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