Evidence for the Lack of Snake Evolution

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Abstract

The fossil record of snakes, when reviewed, shows no evidence for the origin of snakes by neo-Darwinian evolution. The most common evolutionary theory is that modern snakes developed from four-legged reptiles that lost their legs. As evidence for this theory, evolutionists point to snake spurs and putative vestigial leg structures that exist on some modern snakes. These spurs and other structures are not evidence of legged ancestors, but rather are functional organs that have an important role in mating. It is also shown that evolution from tetrapod to snake would require major anatomical changes in the skeleton and the body organs as well as the production of several new organ systems, such as the sensory system.

Introduction

Feared by many—and worshiped by some—snakes are found in almost every part of the world. Snakes (suborder Serpentes or Ophidia), one of the most specialized vertebrates known, boast 18 families, each one containing hundreds of species, totaling about 3,000 species (Holman, 2000; Mattison, 2007). Only about 400 of the 3000 species are venomous, and fewer than 100 species are dangerous to humans.

Snakes can thrive in an enormously wide variety of habitats. Besides terrestrial and sea snakes, there exist burrowers, climbers, crawlers, and even air gliders, each of which, if it evolved, should have

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left some evidence in the fossil record of its descent (e.g. Shine, 1991, p. 37). Evolutionists suggest that snakes evolved from either four-legged, lizard-like, land animals or aquatic (or perhaps amphibious) vertebrates that came to shore to breed and lay eggs (Simon, 1973). Their evolution should be easy to document because the "evolution of snakes involved major changes in the vertebrate body plan organization," as reflected in the skeleton (Cohn and Tickle, 1999, p. 474). Although the typical lizard and the typical snake possess a number of traits in common, many major anatomical and physical differences exist between them (Parker and Grandison, 1977).

The Differences Between Tetrapod Reptiles and Snakes

Differences between the common tetrapod reptile and a snake include not only the fact that snakes lack limbs but also that they have a greatly increased number of vertebrae—from 120 to as many as 500 compared to 32 in humans, and approximately the same number of thoracic vertebrae typically found in lizards (Benton, 2005). Snake vertebrae are also more complex with extra processes on the neural arches that control the sideways movement and bending of its long body (Benton, 2005). Their vertebrae are connected to curved ribs that lack differentiation of the neck, thorax, abdomen, and other major body parts. A snake's elongated body requires either a reduction of paired internal organs, such as lungs or kidneys, compared to other reptiles, or a normally paired organ positioned so that one organ is located behind the others, allowing the orgasm

to fit within the snake's long, slender, legless body.

Snakes are so well designed for several different types of movement that they have been able to effectively occupy an amazingly large variety of ecological environments (Holman, 2000). The snake's very flexible, long skeleton allows it to travel by sinuous side-to-side lateral undulations, similar to the method by which an eel swims (Parker and Grandison, 1977). Their mode of travel is so efficient that some snakes can travel as fast as seven miles per hour. On sandy or muddy surfaces snakes use a sidewinding movement; on slick surfaces they use a slide-pushing and concertina locomotion. They also can use a saltation movement, involving jumping forward by rapidly stiffening its body from head to tail (Holman, 2000). Snakes can flatten themselves, enabling them to squeeze through cracks smaller than their bodies. They can even vigorously spin their bodies to escape enemies when seized by the tail (Holman, 2000).

The snake, *Chrysopelea ornate*, can flatten itself to the degree that it can actually glide like a flying squirrel and, for this reason, is called a "flying snake." Some snakes are excellent climbers and can spend most of their lives in trees. Others are fossorial (earth burrowing) with vermiform (wormlike) bodies that are designed to burrow. Snakes can swim using lateral undulations to propel themselves through the water. Sea snakes have a caudal fin that enables them to swim much like fish. Some snakes even lock their vertebra to form a stiff polelike structure that allows them to stretch horizontally from one tree limb to another. Achieving all of these abilities requires a uniquely designed vertebral system.

Eels, caecilians, some amphibians, and certain lizard species are also limbless like snakes. All of these vertebrates, though, differ markedly from snakes. Eel and caecilian possess vertebrae that are simple biconcave spindles, and legless

lizards often have simple, flat-bottomed vertebrae (Holman, 2000).

Snake skulls are of a very light construction, and, in contrast to lizards and other reptiles, their braincase is both low and flat (Carroll, 1988). A snake can easily swallow prey two or more times the diameter of its own body. Their jaws use kinetic (movable) skull and jaw systems that form a "swallowing machine that is unique among terrestrial vertebrates" (Holman, 2000, p. 4). Their double-jointed jaw hinge moves backward and then forward so as to move their prey, which they swallow whole, down towards their elongated stomach; this technique is called unilateral feeding (McClung, 1993).

The double jaw hinge allows for large gape expansion to permit snakes to swallow prey two to three times as thick as its body diameter. The "remarkably stretchable skin is also *designed* to swallow very large prey" (Holman, 2000, p. 6, italics added). Digestion begins in the mouth and continues along the digestive track, where finely tuned, powerful digestive enzymes rapidly break down prey.

The enormous contrast between tetrapod reptiles and snakes makes the study of snake evolution an excellent test of the theory of common descent. As Holman noted, just observing a "disarticulated snake skeleton in a box one immediately senses the *uniqueness* of these animals" (Holman, 2000, p. 4, italics added). For example, snake vertebrae have more extra-articular surfaces than any other vertebrate group known (Holman, 2000). These distinct skeletal differences make it comparatively easy to identify snakes in the fossil record. In contrast, lizards have a skeleton far more like a typical mammal then a snake.

Snake Sensory Systems

The snake's sensory systems are very different from that of most other reptiles (Simon, 1973). Unlike most lizards, snakes lack external ears and hence

cannot "hear" sound, but instead sense ground vibrations. The eye design of snakes is also very different from that of lizards. Snakes do not have movable eyelids as do most lizards (a gecko is one exception), and snakes have a transparent cap called a brille that covers the eye (as do most crocodilians), offering extra eye protection. Snakes also smell and taste through their flickering forked tongue, which uses a highly innovative chemoreception system located inside their mouth (Holman, 2000). This last trait is more common among lizards.

A snake's tongue is unique in that it can extend to the outside of the head without opening the mouth (Simon, 1973). The tongue is associated with a paired vomeronasal (Jacobson's) organ to form a sophisticated chemoreceptor system used to evaluate chemical information that can tell the snake much about the air, ground, water, or even potential prey. Pit vipers have what are called "sensory pits" between the nostrils and eyes, which are "probably the most sensitive heat receptors in the zoological world," so sensitive that they are able to detect both the direction and distance of warm objects (Holman, 2000, p. 6).

Snakes' eyes are actual image-forming systems working in the lower energy portion of the infrared spectrum, just below visible light. This is why these reptiles can enter a deep burrow in total darkness to find, kill, and consume prey. In contrast, honey bees and certain other insects can "see" well into the ultraviolet portion of the electromagnetic spectrum, enabling them to see the sun and navigate even on heavily overcast days.

Evolution of Venom

If snakes evolved, these many unique snake traits must be explained by neo-Darwinian descent. However, plausible evolutionary scenarios are distinctively absent. For example, snakes have the "most efficient venom-injecting system ever evolved in terrestrial vertebrates"

(Holman, 2000, p. 4), but how "it came about that snakes manufactured poison is a mystery" (Crompton, 1987, p. 69). One theory is that their toxin was once saliva produced by mouth digestive glands, and the saliva glands evolved into poison glands. The problem with this explanation is that the use of toxin

> was not forced upon them by the sur- vival competition; they could have caught and lived on prey without using poison just as the thousands of non-poisonous snakes still do. Poison to a snake is merely a luxury; it en- ables it to get its food with very little effort, no more effort than one bite. And why only snakes? Cats, for in- stance, would be greatly helped; no running fights with large, fierce rats or tussles with grown rabbits—just a bite and no more effort needed. In fact, it would be an assistance to all the carnivorae—though it would be a two-edged weapon when they fought each other. But, of the vertebrates, unpredictable Nature selected only snakes (and one lizard). One wonders also why Nature, with some snakes, concocted poison of such extreme potency (Crompton, 1987, p. 69).

Another problem with the specula- tion that saliva evolved into venom is that snakes can manufacture very different poisons that function in very different ways. Some act on the nervous system (neurotoxic), which causes paralysis and blocks the nervous system. Another type, called the hemolytic poison, acts on the blood-clotting system and breaks down the capillaries, causing internal bleeding. The problem for evolution is that the toxin apparatus is a complex unit with many irreducible parts. For ex- ample, the poison glands are connected to specially designed teeth, and the brain and nervous system must coordinate the whole system (Holman, 2000).

These are just a few of the major differences between snakes and other reptiles. A major skeletal trait of snakes is limblessness, and it is this trait on which many evolutionists focus for evidence of evolutionary descent.

Theories of Snake Origins

The two most popular theories for the origin of snakes by neo-Darwinian evolu- tion are that they arose from small fosso- rial lizards or that they had a more direct aquatic origin (e.g. Holman, 2000, p. 7). Ellis added that for sea snakes it is not even "evident whether snakes evolved as aquatic animals and then some came out on land, or whether they are land ani- mals, some of which returned to the sea" (Ellis, 2001, p. 151). Sea snakes have nu- merous unique traits in contrast to land snakes, indicating a "separate evolution" (Ellis, 2001, p. 15). Sea snakes possess special features allowing them to stay submerged for extended times and dive to considerable depths.

The many changes required to evolve terrestrial snakes into sea snakes would include evolution of a thin mus- cular tail to allow them to move through the water and both salt excreting glands and valvular nostrils to keep out seawater. They would also need a radically modi- fied breathing apparatus and a much larger set of lungs to allow them to stay under water. The transition to a marine animal would involve much more than lung size changes; it would also require larger hemoglobin and myoglobin levels, a larger and differently designed muscle system, and a host of other adaptations existing in diving mammals.

The theory that snakes evolved from burrowing lizards has been postulated as a more feasible alternative. Although many differences exist between snakes and burrowing lizards, they both possess some remarkable similarities, including intrinsic eye muscles and lack of struc- tures such as eyelids, tympanum, and middle ear cavities. Because there are many major differences between vari- ous kinds of snakes, different phylogeny has been postulated for several groups of snakes. Egg-laying sea snakes, for ex- ample, are theorized to have arisen from "terrestrial elapids or perhaps from a very early Australian species" of some type, a theory also lacking fossil evidence (Ellis, 2001, p. 152).

Most theories of snake origin state that snakes evolved from tetrapod ancestors, requiring loss of their limbs (Caldwell and Lee, 1997). The many other modifications required for snakes to evolve from tetrapods include loss of legs and their appendicular muscle, loss of the appendage system, and the evolu- tion of a whole new complex system of axial muscles to move the body. This includes complex mechanisms involving bone, nervous, and brain structures that allow snakes to travel by some type of serpentine locomotion (Holman, 2000). The common theory of snake evolution is that when fish first "invaded land they had to make several radical anatomical alterations" (Crompton, 1987, p. 11) in order to survive on land. For example, they had to evolve legs, since the better adapted they were moving in water, the less adapted they were to traveling on land. Crompton added that among the

> fishy mob of pioneers were the foreparents of snakes and men, and these, together with the rest, grew legs. Not very good ones, but they improved as time went on, and time did go on: many millions of years passed and the snake still ran about on legs. Then, towards the beginning of the mammalian era, when the reign of the reptiles was drawing to a close, the snake discarded its legs. Now the fishes grew legs because they could not move about on land without them, and it seemed quite impossible that any vertebrate with well-developed ribs and backbone could do so. How did the snake get on? Well, had it held a theory about legless propulsion and set about to prove it, it could not have succeeded better. ... Legless, it can travel as fast as a human being, climb trees, travel

along the top branches, shooting from there like an arrow and resuming its rapid course along the ground, and it can rejoin the element from which it came, its new shape enabling it to swim fast and gracefully (Crompton, 1987, pp. 11–12).

This "just so" story lacks evidence, fossil and otherwise.

Potential Transitional Forms

The three most important snake fossils used to argue for snake evolution are the Squamate (snakelike) *Pachyrhachis*, *Lapparentophis* (a 1.5 meter-long reptile with 146 presacral vertebrae), and *Dinilysia*, all known back to the Cretaceous (Holman, 2000, p. 8). The theory that snakes evolved from an aquatic animal is supported by the marine creature, *Pachyrhachis problematicus*, an animal similar to varanoid lizards; a species that includes a large number of aquatic lizards. Of all known

> modern lizard groups, the varanoids are most similar to snakes. These similarities include (1) the type of tooth replacement that occurs, (2) the detailed structure of the tongue and vomeronasal organ, (3) some cranial characteristics, and (4) the presence of an intermandibular joint in the lower jaw.... *Pachyrhachis* and *Ophiomorphus* from the early Upper Cretaceous were snakeline in body form, had similar vertebrae to snakes, and completely lacked forelimbs and girdles (Holman, 2000, p 7).

Although Carroll concluded that *Pachyrhachis* and *Ophiomorphus* "may be intermediates between" snakes and varanoid lizards, much evidence exists against this position (Carroll, 1988, p. 237). From their study of *Pachyrhachis* and *Ophiomorphus*, Caldwell and Lee (1997) concluded that they were the same animal because, although *Pachyrhachis* had a "slightly" more pronounced pachyostotic rib structure (ribs thought to be adapted for a marine

existence) than *Ophiomorphus*, the two genera were "otherwise almost indistinguishable" (Caldwell and Lee, 1997, pp. 705–706). They also concluded that *Pachyrhachis* had many non-snake traits, including a well-developed pelvis, sacrum, and hind limbs that included a femur, a tibia, a fibula, and tarsals (Caldwell and Lee, 1997). This evidence strongly argues that *Pachyrhachis* was not related to snakes but rather was a long-bodied varanoid lizard.

Furthermore, evidence indicates that *Lapparentophis defrennei* was about the same "age" as *Pachyrhachis*, removing it from the fossil ancestor position. Mattison (2007) wrote that the "earliest known snake is *Lapparentophis defrennei*," but no evidence exists of a "link with earlier snake-like reptiles and so its origin is a mystery" (p. 13). It appears that this oldest snake, *Lapparentophis defrennei*, is merely an extinct snake and not a transitional form.

Another proposed snake transitional fossil is *Dinilysia patagonica*. *Dinilysia*, a large-bodied, six-foot-long animal, is the first known snake in which the skull—which resembles that of a pipesnake but appears to have some lizardlike snake traits—is well documented (e.g. Greene, 1997, p.271, 274). Dated from the upper Cretaceous, it is a modern snake in design, and for this reason is called the first known snake. Its vertebrae are "clearly those of snakes" (Carroll, 1988, p. 235), but it has some minor lizard traits (Holman, 2000, p. 8). The existence of this snake has been known since 1901, and a large number of exceptionally well-preserved skulls and skeletons are now known to exist. For this reason we can arrive at many conclusions about the animal with some confidence, including *Dinilysia* is an extinct snake—and not a transitional form.

Nonetheless, *Dinilysia* "has inspired and challenged efforts to understand snake origins" (Greene, 1997, p. 274). Specifically, the fossil inspired the theory that snakes evolved from an

animal that structurally resembled an Asian pipesnake, a view that Greene concluded is unlikely: "A more likely alternative is that the earliest snakes were small creatures and, like limbless anguimorphs and blindsnakes, primarily ate tiny arthropods" (Greene, 1997, p. 271).

In summary, the "question of whether snakes evolved from burrowing or aquatic lizard ancestors is still open to argument, and the knowledge of the origin of snakes gained from the fossil record remains cloudy" (Holman, 2000, p. 8). Carroll speculated that the

> ancestors of snakes probably diverged from the lizards before the end of the Jurassic. Although the evidence is not conclusive, their affinities are probably close to the base of the varanoid stock, from which their primary specialization was toward great elongation of the body and limb reduction. The early members may have been relatively large terrestrial carnivores that became further specialized by an increase in jaw mobility that enabled them to swallow prey whole. Great elongation of the body and a relative reduction of its girth would have preadapted snakes for both aquatic locomotion and burrowing, which have been elaborated in divergent lines many times during their evolutionary history (1988, p. 236).

The Monitor Theory

Another theory is that snakes evolved from reptiles known as monitors. The problem is that most monitors are fairly large and move in jerks very unlike a snake. The monitor family includes the Komodo dragon, a large lizard now existing in only a few small East Indonesian islands. It bears a striking resemblance to the mythical dragon of legends. One characteristic typical of many monitors is that they, like snakes, swallow their food whole without chewing (Simon,

1973). The evidence for a monitor-snake ancestor is clearly based on an arbitrary selection of certain anatomical features that are shared by both snakes and monitors, ignoring many others in order to

> link them to some common ancestor. Neither the snakes nor the monitors can break off portions of their tails voluntarily and later regrow them—an ability that is a hallmark of other lizard groups, including the legless worm lizards that superficially look enough like snakes to be frequently mistaken for them. The breakable tail is a handy defensive device permitting many a lizard to escape while its enemy is tackling the wriggling tail tip. Lacking this ability, a monitor or a snake that loses a portion of its tail must live for the rest of its life with a permanently shortened tail. Another feature attesting to the relationship between the two groups is the long, flexible, forked tongue, which is used to pick up the scent of prey with the help of a taste-sensitive organ located in the roof of the mouth. Jacobson's organ, as it is known to zoologists, is most highly developed in snakes, but in monitors it is much more developed than in [most] all other lizard groups (Simon, 1973, pp. 31–32).

The problem with postulating evolutionary trees by comparing morphological traits of living animals is illustrated by the fossorial and aquatic lizard theories. This method is largely conjecture, with a lack of fossil or other evidence to demonstrate the claim. A vertebrate paleontologist who carried out research in the last decade on snakes has concluded that since 1997,

> twenty or more papers have appeared that purport to tackle the question of snake origins. The issue is still unresolved: are the snakes closely related to amphisbaenians, or are they part of the anguimorph clade, close to the mosasaurs and aigialosaurs (mosasauroids)? If the former, their origin

is from land-dwelling burrowers, if the latter, snakes were primitively marine (Benton, 2005, p. 291).

The Fossil Record

The fossil record of snakes is comparatively limited because snake skeletons are especially fragile. In the majority of cases only disarticulated vertebrae, ribs, and a few cranial bones are found (e.g. Parker and Grandison, 1977, p. 11; Holman, 2000, p. 4). A major means of differentiating snakes from lizards is the morphology of individual vertebrae, which often cannot be determined from the fossil record due to its incompleteness (Holman, 2000). Fortunately there "are wonderful exceptions to the poor fossil record of snakes," including a number of essentially complete skeletons (Greene, 1997, p. 274). However, these "wonderful exceptions" in the fossil record have not been very helpful to evolutionists.

Although "it is now accepted that snakes arose from lizards," Parker and Grandison (1977) admitted that "no specific designation of the ancestral group can yet be made" (p. 11) because the fossil record provides no evidence for any specific evolutionary path. More recently, Mattison (2007) concluded that no fossil evidence links snakes to lizards in spite of the fact that enough fossil evidence exists to conclude that "by the time the dinosaurs became extinct, snakes had already diversified and became widespread" (p. 11). In other words, a wide variety of snakes existed early in the fossil record, and, although many papers exist documenting adaptive and microevolutionary changes, no evidence of their evolutionary descent from lizards or other non-snakes exists.

Formal collections of snake fossils date back at least to the middle 1800s (Holman, 2000). The oldest snake fossils are dated by evolutionists as belonging to the Early Cretaceous period, about 95 million years ago, and they radiated

greatly during the Tertiary (Greene, 1997; Benton, 2005). The first snakes appear in the fossil record very early—estimates range from 100 to 150 million years ago (Mattison, 2007, p. 11). Only vertebrae have been found that are considered "unquestionably snake like" (Parker and Grandison, 1977, p. 11). The reason only vertebrae have been found may be that snakes did not evolve from tetrapods.

The claim that snakes are the "most recently evolved of all the reptilian lineages" and "appear later in the geological record than any other reptile" argues that, if they evolved from tetrapod fossils, evidence of their evolution should be abundant in the fossil record (Holman, 2000, pp. vii, 1). The first clearly recognized snake in the fossil record is *Lapparentophis defrennei*, dated from the Lower Cretaceous about 130 million years ago and found in the Sahara desert (Parker and Grandison, 1977, p. 11). Although only its vertebrae have been found, their distinctive features are unquestionably snakelike (Parker and Grandison, 1977, p. 11).

The very first snake fossils, as far as we can determine from the extant evidence, are characterized by all the same traits found in modern snakes, including an elongated body, greatly reduced limbs and eyes, a highly developed chemosensory system, and cloacal scent glands used for defense (Greene, 1997). A key trait needed to support snake evolution from tetrapods is the progressive streamlining and elongation of the snake body in the fossil record. The common theory is that once the snake body was long enough and undulant motion was perfected, the legs were no longer needed and possibly even a hindrance (Palmer, 1992).

The assumption that these snakes had legs in their evolutionary past but slowly lost them through evolutionary selection completely lacks fossil evidence. The only evidence for loss of legs is the putative leg remnant, which, as we will

show, is actually not a leg remnant but a functional organ. Also, in spite of the "discovery of limbed snakes with hind limbs, the precise group that gave rise to snakes remains uncertain and hotly contested" (Bejder and Hall, 2002, p. 452). Gradual loss of a bone-based structure, such as the loss of legs, would have been well preserved in the fossil record if this gradual loss had actually occurred. It would also seem such ancestral snakes would be at a huge selective disadvantage as their legs were becoming reduced in size but still not allowing the required streamlined body. It is difficult to postulate an advantage for these intergrades, and, if they in fact existed, it is difficult to explain their absence in the fossil record. Although many skinks (*Scincidae*) have very reduced limbs, they also have another adaptation allowing them to fold their limbs to one side during locomotion.

A major problem that results from lack of fossil evidence includes the fact that the "origin of snakes is largely speculative and little documented. Their fossil record is scanty and in the great majority of cases based only on vertebrae" (Parker and Grandison, 1977, p. 11). Stahl concluded, "The origin of the snakes is still an unsolved problem," and Colbert added, "Unfortunately, the fossil history of the snakes is very fragmentary, so that it is necessary to infer much of their evolution from the comparative anatomy of modern forms" (Stahl, 1974, p. 318; Colbert et al., 2001, p. 154).

Some paleontologists have pointed to a fossil known as *Pachyrhachis problematicus* as the ancestor to snakes because it appears to have had very tiny legs and a pelvic girdle. This find, though, "exhibits such a blend of snakelike, lizardlike, and unique characteristics that herpetologists still argue about whether this creature was indeed a snake" or just a unique animal (Greene, 1997, p. 274).

In spite of the lack of evidence, it is now widely "accepted that snakes arose

from lizards, although no specific designation of the ancestral group can yet be made" (Parker and Grandison, 1977, p. 11). Nonetheless, debate continues as to whether or not any modern lizard families are evolutionarily related to snakes, and there even exist "conflicting views as to the environment in which snakes evolved" (Carroll, 1988, p. 235). To explain modern snakes, some herpetologists propose that they evolved in many environments, postulating a burrowing stage, followed by a land-surface stage. Others herpetologists argue that snakes never went through a burrowing stage.

Snakes resembling modern pythons have been found in the fossil record estimated by evolutionists to date back 95 million years, specifically *Haasiophis* and *Pachyrachis*, which evidently had limblike structures located on their caudal posterior. Both of these animals, though, were fishlike aquatic animals with flattened tails, indicating they are not transitional forms (Sodera, 2003).

Significantly, none of these snake fossils shows "even a trace of the pectoral girdle or forelimbs" (i.e., shoulder blades, collar bones, etc.) or breast bone (Carroll, 1988, p. 234; see also Parker and Grandison, 1977, p. 11). More recent studies confirm their lack of even a trace of a pectoral girdle and forelimbs (Cohn and Tickle, 1999; Burchfield et al., 1982). In those fossils clearly recognized as snakes, only vertebrae have been found and no clear evidence of limbs. One possible exception to lack of limbs and girdles is *Najash rionegrina*, which has a sacrum, a supporting pelvic girdle, and "robust functional legs outside of the ribcage" (Apesteguia and Zaher, 2006, p. 1037). The problem with this fossil as an example of snake evolution, however, is that it appears to be a limbed snake, not a snake losing its limbs:

> *Pachyrhachis problematicus*, *Haasiophis terrasanctus* and *Eupodophis descouensi*, three marine fossil snakes from the Tethyan coasts of

Northern Gondwana, were until now the only known snakes with well-developed hindlimbs. The presence of fully formed hindlimbs enforced the idea that these were the most primitive (basal) snakes and perfect transitional taxa linking extant snakes to an extinct group of marine lizards, the Mosasauroidea. However, the presence of several other features typical of the more advanced macrostomatan snakes such as pythons, boas and colubroids supports the competing hypothesis that these fossils were advanced (macrostomatan) snakes instead, with no special bearing on the origin of snakes (Apesteguia and Zaher, 2006, p. 1037).

As Greene noted, new fossil snakes are now being "discovered even more frequently, and with luck and careful study," these fossils will help us further understand snake origins (Greene, 1997, p. 275). So far all of the many discoveries have made the mystery of their evolution even more elusive and serve instead as examples of intelligent design.

Loss of Limbs

Lacking a convincing fossil record, herpetologists rely on comparisons of extinct and living organisms to "infer changes in their attributes through time," as well as research on embryonic tissue interactions and shifts in developmental timing (Greene, 1997, p. 271). One major trait that is used to infer changes is the existence of spurs.

One of the earliest views of snake origins is that they lost their limbs and acquired their long, thin, legless bodies by trying to squeeze through tight places (Palmer, 1992). The two other theories as to why snakes lost their legs are:

> the ancestors of snakes had legs and that those limbs were lost either in a burrowing lizard that required legs less and less, or in a marine form that lost its limbs as it came to rely more

and more on serpentine locomotion (Benton, 2005, p. 241).

As evidence for the theory that limbs were lost, herpetologists point to what they claim are rudimentary legs in snakes, organs that are actually spurs. An evaluation of whether these spurs are vestigial legs concluded that they are not, but they are functional (Bergman and Howe, 1990). To maintain the loss-of-limb theory in the face of much contradictory evidence, herpetologists have been forced to postulate that leglessness has "evolved independently in several unrelated lizard families" (Mattison, 2007, p. 11).

Although it is commonly thought that snakes underwent a progressive loss of limbs, recent "paleontological discoveries suggest a more complex scenario of limb reduction," an event that is "still poorly documented in the fossil record" (Apesteguia and Zaher, 2006, p. 1037). One reason why a more complex scenario is postulated is that many extinct forms exist—some that had limbs, and others that did not—and they lived contemporaneously, ruling out an ancestral relationship for the limbed forms.

Snake Spurs

One of the more commonly cited evidences of snake evolution is the presence of claws or spurs on the posterior part of a few types of snakes. Darwin concluded that these snake spurs are "rudiments of the pelvis and hind limbs" that are evidence of the evolution of snakes from limbed ancestors (Darwin, 1859, p. 450). Since then Darwinists have used the argument that the support system for these clawlike, horny spur structures are vestigial "legs" left over from the snakes' limbed past. Bobrowsky (2005) used this claim to argue against Intelligent Design by claiming that many animals

> contain both nonoptimal characteristics and vestigial organs, both of which would not be expected from a truly intelligent designer.... Examples of vestigial organs include

> ... the vestigial leg bones in whales and snakes. These characteristics would be expected from evolutionary development but not from an intelligent designer. (p. 12)

It is still further claimed that

> even at the present time, the snake has not entirely got rid of its legs. At least, tiny, vestigial remains of what were once hind legs are found inside the bodies of many snakes, while the python has two small external protuberances as leg relics, and carries in its inside the remains of a pelvis (Crompton, 1987, p. 12).

Their primary support for the view that spurs represent somewhat vestigial legs is the fact that spurs are anatomically in a location roughly similar to where the hind legs develop in other reptiles. But the "vast majority" of snakes do not have evidence of

> vestiges of hind limbs or a pelvis either; only in the boas and pythons and three other small groups are there persistent remains of hind limbs, which usually appear externally as small horn-sheathed claws ..., and some vestiges of a pelvis inside the ribs. Reduction of limbs to the same extent also occurs, however, in amphisbaenians and in some lizards (e.g., Slow-worm, Glass-lizard, etc.) and these, like the snakes, progress mainly by sinuous side-to-side undulations of the body in much the same way that an eel swims (Parker and Grandison, 1977, p. 11).

Evolutionists interpret the pelvic bones and the spurs in certain snakes as "vestigial pelvic bones and anal spurs that represent the remnants of hind legs. These remnants of legs have, of course, lost all function in locomotion" (Griehl, 1982, p. 11). The common claim is that all modern snakes have lost all traces of their forelimbs but some have retained very small rudiments of their hindlimbs.

The vast majority of snakes have no vestiges of hind limbs or of a pelvis (Park-

er and Grandison, 1977, p. 10). Snakes that do have putative traces of pelvic and lower limb bones include only pipesnakes (Anilidae), boids (boas and pythons), blindsnakes (Typholopidae), and worm snakes (Leptotyphlopidae). In most snakes that have these "legs," including the anaconda and the python, the end parts are slightly exposed and form small horn-sheathed claws (Williams, 1970; Carr, 1963; Iverson, 1986: Murphy et al., 1978).

Congenital abnormalities, such as the ones caused by the drug thalidomide involving misshapen limbs in humans, cause the maldeveloped/shortened limbs to appear *outside* of the body surface, not embedded deep within it as is the case of the "pelvic" bones of living and fossil snakes and whales. This indicates that the so-called "pelvic" bones of living and fossil snakes and whales are not homologous to rear limbs. Comparisons of the snake's so-called "limbs" with the extinct dolphinlike *durodontine*, which definitely had tiny rear limbs outside of its body, illustrate this.

These vestigial limbs are used as evidence that the ancestral snake was a lizardlike animal or a lizard that lost its legs as it evolved (Murphy and Henderson, 1997). One problem with this conclusion is that some lizards have both legs and spurs (Sodera, 2003). How and why snakes lost their limbs "remains enigmatic" (Bejder and Hall, 2002, p. 452). Reasons given include the claim that it gives the snake better mobility in the underbrush. Many leg-possessing creatures are very mobile in underbrush, and loss of legs would seem to put snakes at a decided disadvantage in the struggle for life.

Another theory to explain their loss of legs is that they "originally lost them adapting to aquatic life" (Hanes, 1999, p. 246). Even if the loss theory is true, such changes show evidence of loss mutations and degeneration, not the evolution of apomorphic structures as is required by Darwinism. The claim that natural

selection once selected for limbs and then later selected against limbs is also problematic. A problem is that tetrapods needed to lose not only legs but many other structures:

> This mobility was not attained merely by shedding the legs. Other alterations had to take place. All inequalities were smoothed out; neck, shoulders, hindquarters went and the snake emerged as a long, symmetrical cylinder. It seemed to have become all tail, though actually it had shortened its tail, which was now merely a small appendage at the end of an amazingly long body. The body, indeed, seemed ludicrously long but the length was just another of those alterations that had to be made for the snake's new method of locomotion (Crompton, 1987, p. 12).

Other changes include snakes having more ribs that have a very different design than limbed animals—and a very different muscle design too. Crompton (1987) added that the "loss of a member in evolution is generally called a degenerate or 'recessive' step, yet most of the improvements of the snake came about by discarding" structures (p. 97). An example includes the fact that in its legged state it possessed eyelids that moved up and down like those of most of the higher vertebrates. It is theorized to have discarded eyelids at the same time it discarded its legs, thus acquiring the fixed, unblinking stare for which it is notorious.

Eyelids lubricate and protect the eyes, but evolutionists claim that this protection was insufficient for a snake, going on its belly through thick, often thorny vegetation or traveling down small holes in search of prey. It also obscured the vision, so a transparent disc was substituted for the eyelid. In other words, the snake put on spectacles, or rather goggles. These goggles are set neatly in the skin and are, in fact, transparent scales, which give full protection to the eyes without obscuring the vision.

The eyes behind are still lubricated and emit water that is drained into a gland, where it is used for other purposes. Gradually, however, the discs get scratched and vision becomes impaired, but the snake sheds its skin several times a year, and with each skin change it gets a new pair of goggles (Crompton, 1987).

It is on the basis of the limb-loss theory that snakes with spurs are labeled "primitive" (Parker and Grandison, 1977, p. 13). The assumption is that "more advanced" snakes, such as colubrids, elapids, and viperids, have lost all traces of their limbs, and the "less evolved" snakes have retained these traces (Murphy and Henderson, 1997, p. 101). A problem with the use of the word "advanced" here is that many "advanced" snakes, such as cobras and vipers, still lay eggs, but some of the snake kinds that are believed to be "primitive," such as boas, which have rear spurs, use "advanced" means of reproduction, meaning they give birth to live young instead of laying eggs (Sodera, 2003, p. 225).

The Function of the Spurs

One claim is that these appendage claws, although very small—particularly in the case of large constrictors—assist in locomotion. The claws would be especially useful when climbing trees (their natural habitat) or when hanging from tree branches (Dewar, 1957, p. 169). Over 150 years ago, naturalist Edmond Gosse wrote that the "spurs" are unquestionably of use to the snake, such as to "help maintain a firm hold on a tree branch while watching for an approaching prey" (quoted in Murphy and Henderson, 1997, p. 101).

Evidence for the spurs' usefulness includes the complex system involved in attaching them to the animal's pelvis. Although morphologically slightly homologous to the femur, they are actually specialized structures. Judging from the bone and muscle structure, the claws do not appear to be vestigial

legs but a specially designed, functional structure (see Figures 1 and 2). The "femur" is constructed from "bone or calcified cartilage of variable shape and development ... [which] bears a cornified claw-like cap" (List, 1966, p. 44) (see Figure 3).

Their claws can be moved by muscles anchored to bone, and the bone-muscle system allows the claws to function as strong grabbers (Bergman and Howe, 1990). They also enable snakes to strike more powerful blows against enemies with its body (Storer and Usinger, 1977). The claws' fighting role is mainly employed in male territorial combat. To effectively achieve this task, the spurs have hard, black-pigmented, horny caps attached to the bone structure (Storer and Usinger, 1977; Cardew and Goode, 2001). Conversely, they cannot be large enough to interfere with locomotion. Sodera (2003) notes that the spurs in a 15-foot-long python he dissected are "comparatively tiny" (p. 225).

A more common claim is that the spurs are used for courtship. Males use these movable spurs to scratch or stroke (and stimulate) the female during courtship and mating (Shine, et al., 2003; Vences and Glaw, 2003; Murphy and Henderson, 1997; Carr, 1963; Parker and Grandison, 1977). Specifically, the spurs are used by the "male to stimulate the female during copulation" (Griehl, 1982, p. 11). The role of the spurs in courting and copulation for the anaconda snake were described by herpetologist R. R. Mole as early as the 1920s (Mole, 1924, p. 237–238).

In one study, the male persistently raked his spurs on the sides of the female's body (Charles et al., 1985). The spurs in females are usually smaller, an indication that scratching is primarily a male courtship behavior. Another study observed that, during the courtship behavior of the Indian python, the

> male would attempt to align his body with the female as she slowly crawled forward. When the female
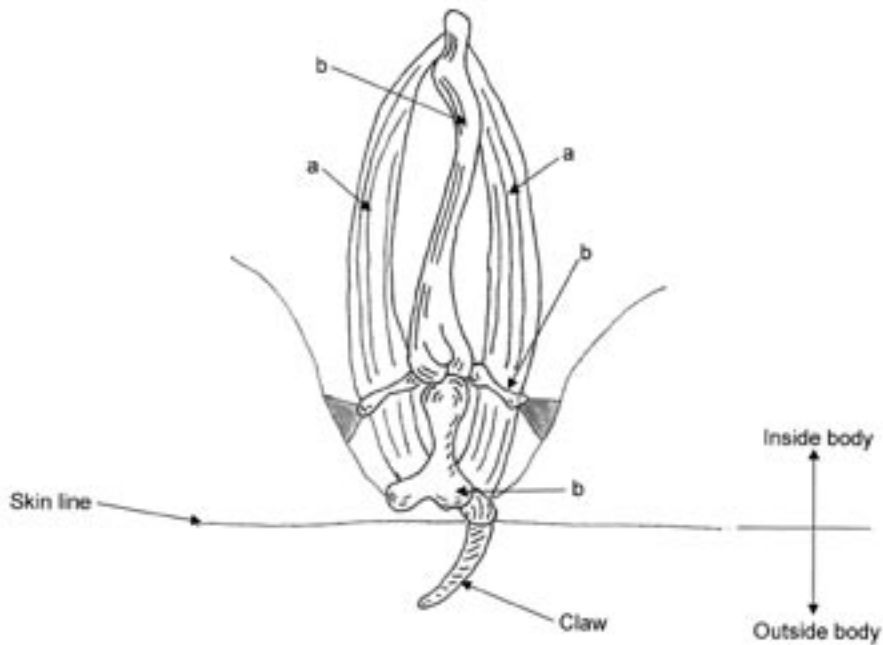
Figure 1. The hind leg skeletal structure and associated musculature from a snake, species not given. Musculature is denoted by "a" and bone by "b." Note it is a complex structure that functions in climbing, fighting, and mating. Originally from Martin (1843, p. 226). Adapted from Murphy and Henderson (1997, p. 102) by B.L. Lindley-Anderson.

Figure 2. The snake claw structure showing it is a well-designed system. The species was not given. These supposed "vestigial" organs have been shown to function for mating and defense uses. Adapted from Murphy and Henderson (1997, p. 102) by B.L. Lindley-Anderson.

Figure 3. A picture of the snake scales and claws, species not given, showing the claw protruding slightly out from the body. This structure plays an important role in mating and defense. Adapted from Murphy and Henderson by B.L. Lindley-Anderson.

would stop forward motion, cease tongue flicking, and raise her head to a height about 75 cm above the substrate, the male would initiate vigorous courtship. The female would hold her position for 10 seconds to several minutes, while the male would loop his body over the female's back and rapidly tongue flick the top of her head and back. The cloacas would then be aligned, and the male would begin vibrating his vestigial limbs 30–80 times per minute against the female's body in the region above her cloaca. At this point the female would sometimes become receptive, arch her tail, gape her cloaca, and the male would insert one of his hemipenes. During the 45–365 minute coitus, the male continued to stimulate the female with his spurs (Murphy and Henderson, 1997, p. 102).

Support for the theory that claws of certain snakes function for courtship includes evidence that the spurs of these snakes protrude "only at the breeding season, functioning in courtship as does the similar spur of some male birds" (List, 1966, p. 44). From this evidence Bergman and Howe (1990) drew the conclusion that the "claws" function during courtship. Reproductive use of these spurs has been reported for reticulated pythons (Lederer, 1944). Evidence that the spurs are used for mating includes the fact that some limbed lizards also have spurs.

Other evidence for spur involvement in reproduction includes the observation that snakes with spurs lack erectile spines that are present in most other kinds of snakes (Boulenger, 2000). Snakes without spurs are forced to mate in very different ways than spurred snakes.
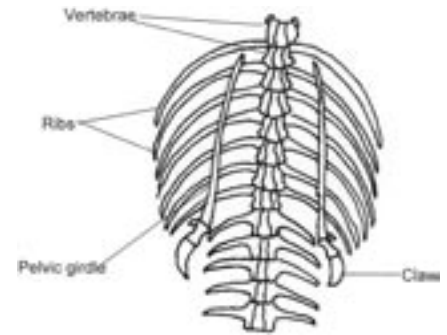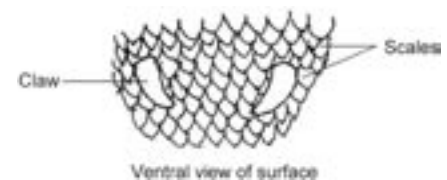
In many of the boas and pythons the next phase of the courtship consists of the male using his claw-like vestigial hind limbs to scratch or stroke his mate's sides, but in 'limbless' snakes the male's body is thrown into a rapid series of rippling waves which run forwards from tail to head. If the female is not receptive these actions evoke no response and the partnership dissolves; but if she is

physiologically ready for reproduction she responds by opening her cloaca and coitus follows (Parker and Grandison, 1977, p. 51).

The snake pelvis and rudimentary legs are also used as evidence against the belief in an intelligent designer. The argument is usually framed as follows: "Vestigial structures, such as the rudimentary pelvis of snakes and whales ... are extremely puzzling if organisms are rationally designed or are constructed according to some universal law" (Barton, et al., 2007, p. 75). As we have seen, these structures are neither vestigial nor irrationally designed but function very well for their intended purpose. Other herpetologists argue that snake limbs were lost and then reevolved again:

> The discovery of limbed snake fossils has raised the possibility, depending on the phylogenetic hypothesis assumed, that limbs also may have reevolved in some snake lineages. Fossils of three marine snakes, *Haasiophis*, *Eupodophis*, and *Pachyrhachis*, present developed hind limbs and were placed in a more derived position than the terrestrial fossil snake *Najash rionegrina*, by Apesteguia and Zaher (2006). This strongly suggests a second evolutionary origin of tetrapod limb in the group. Some authors claim that this idea would be reinforced by the evidence for regulation of vestigial leg morphogenesis in living pythons by hox genes (Kohlsdorf and Wagner, 2006, p. 1908).

Conclusion

Snake evolution from non-snakes should be relatively easy to document in the fossil record because of major structural changes required to evolve from its hypothetical tetrapod ancestors. Our review has supported Parker and Grandison's (1997) conclusion that, although a large number of excellent snake fossils have

been found, no fossil evidence exists for its putative evolution and, therefore, the "origin of snakes is largely speculative and little documented" (p. 11). The fact is that the "competing phylogenetic hypotheses for snake origins are controversial and under constant debate" (Kohlsdorf and Wagner, 2006, p. 1908). Although it is widely believed that snakes evolved from some type of lizard, no viable evidence of their specific lizard relatives have ever been identified (Caldwell and Lee, 1997, p. 705).

For this reason "how the origin of snakes from lizards took place is still a matter of conjecture" (Holman, 2000, p. 7). The reason is because the earliest snakes are clearly snakes, and although an enormous amount of variety exists, no fossil evidence of snake evolution from lizards or another non-snake creatures exists (Hennigan, 2005). Furthermore, Holman (2000) added that he "will not make a judgment call as to the origin of snakes ... because in vertebrate paleontology, one learns that about the time one hypothesis is chosen over the other, a new fossil is found that changes the picture" (p. 8). For this reason the phylogeny of snakes is based almost entirely on the anatomy of living animals (Carroll, 1988, p. 236).

Acknowledgements

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