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Under the hood

Snakes have evolved in amazing ways, says **Bob Holmes**, and losing their legs was the least of them

SNAKE! Just the thought is enough to trigger a spasm of fear in many of us. Snakes make biologists' hearts beat faster, too, but for a different reason: in evolutionary terms, they may be the most surprising group of vertebrates on Earth.

Their long, legless bodies, it turns out, are the least remarkable thing about them. It's on the inside that snakes have made extraordinary changes. They have pared down their internal organs, mostly eliminating one lung and all but one lobe of the liver. They have evolved a novel heat-detecting sense organ and the most sophisticated venom system of any animal, and they can turn their metabolism up and down more dramatically than any other vertebrate. This re-engineering even extends to the molecular level – proteins that have remained unchanged across other vertebrates have been rebuilt in snakes.

"It looks like evolutionarily, snakes are a kind of redesigned organism," says Stephen Mackessy, who studies snakes at the University of Northern Colorado in Greeley. And with the help of the first two snake genomes to be sequenced, we are beginning to piece together their remarkable evolutionary journey.

The story of how snakes evolved begins just over 100 million years ago, with a lizard or lizard-like reptile. Biologists are still debating about exactly which group the ancestor of snakes belonged to. A few think snakes are descended from the marine reptiles known as mosasaurs, but they are in the minority. "I think the great bulk of the evidence points to a terrestrial origin for snakes, and even a burrowing or secretive origin," says Harry Greene, an evolutionary biologist at Cornell

The success of snakes is due to some remarkable internal re-engineering

University in Ithaca, New York.

The mainstream view is that proto-snakes belonged to a group whose living representatives include the monitor lizards and Gila monsters. So why did some members of this group lose their legs and elongate their bodies? Most likely it was to chase insects through subterranean burrows or tangles of grass. Indeed, the most primitive snakes found today – a group called the blind snakes because of their vestigial eyes – still live underground feeding on ants and termites, supporting the notion that the earliest snakes might have been burrowers.

"The difference in metabolism between a live snake and a dead snake is minimal"

Acquiring a snake-like body involved surprisingly few mutations. The "grow limbs here" genes are still active in snake embryos, says Michael Richardson, a developmental biologist at Leiden University in the Netherlands, but the cells in these areas just ignore the signal, so no legs form. Snakes get their long bodies by budding off vertebrae at an unusually fast rate as embryos, so that they end up with many more than other animals – over 500 in some species.

In fact, it appears to be really easy for lizards to evolve a snake-like body, as it has happened on numerous occasions. "There are dozens of lizard lineages that have lost their limbs, " says Michael Lee, an evolutionary biologist at the South Australian Museum in Adelaide. Most, however, are small burrowers, seldom seen and little studied.

Extraordinary abilities

The ancestors of snakes, by contrast, slithered back above ground and started to hunt larger prey, eventually giving rise to fearsome predators such as rattlesnakes and cobras. There are around 3400 species of snake today, found everywhere except in the coldest polar regions. Some have colonised tropical seas, and never touch dry land. Others, like boas and pythons, have grown very large – although even the biggest snakes living today are small compared with Titanoboa, an extinct snake that grew to more than 10 metres in length and weighed over a tonne. No other group of legless lizards is as diverse and widespread. "None of them are as successful as snakes," Lee says.

What makes snakes special, then, are the less obvious changes that occurred after their ancestors lost their legs. In particular, snakes have some extraordinary metabolic abilities. These started to evolve very early on; blind snakes – which branched off early in snake evolution – show extensive changes to their mitochondrial genes that may have allowed proto-snakes to burn less energy by turning down their metabolism.

This paved the way for the very effective strategy early snakes adopted as they moved back above ground: eating occasional big meals rather than lots of little ones. As a result, snakes don't have to spend all their time hunting – when they are vulnerable to being preyed upon themselves – and can cope ›