VETERINARY TODAY INTERNATIONAL
ISSN 2583-8288

Snake Anatomy and Its Evolutionary Adaptations

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DOI:10.5281/veterinarytoday.18753597

Abstract

Snakes are elongated, limbless reptiles belonging to the class Reptilia, with more than 3,500 species distributed worldwide. Despite their diversity, they share a similar basic body structure adapted for survival and predation. Their flexible skeleton, numerous vertebrae and ribs, and loosely connected jaws allow them to move efficiently and swallow prey whole. Specialized teeth and, in some species, venomous fangs assist in capturing and subduing prey. Snakes possess well-developed sensory systems, including heat detection and Jacobson's organ, which enhance their ability to locate food and perceive their environment. Their internal organs are elongated to fit their slender body, and unique respiratory and circulatory adaptations support their feeding habits. Overall, the anatomical features of snakes reflect remarkable evolutionary adaptations that enable them to thrive in diverse habitats across the world.

Keywords: Anatomical, Body, Non-venomous, Snakes, Venom, Vertebrae

Introduction

Snakes belong to the class *Reptilia*, order *Squamata*, and suborder *Serpentes*. Although more than 3,500 species of snakes are found worldwide, their basic anatomical structure remains largely similar across species (Pollock, 2020). Snakes feed primarily on animals such as birds and mammals that maintain a constant body temperature. These warm-blooded animals can be detected by snakes through their ability to sense body heat (Peters and Wallach, 2026). Snakes are characterized by an elongated body with a distinct tail and the absence of limbs. Their skin is covered with scales, which can be smooth or rough. The scales on the belly are larger and thicker than those on the sides and back. These belly scales help protect the body and help the snake move. Snakes do not have legs, movable eyelids, or external ears. In most non-venomous snakes, the teeth are arranged in two rows on the upper jaw and one row on the lower jaw. The teeth curve backward, which helps hold the prey and stops it from escaping (Divers, 2024).

1. General body structure

a. Jaws

Snake jaws differ from those of most other animals, particularly in their ability to open widely. As snakes do not chew their food, their jaws are adapted to swallow prey whole. The lower jaws are loosely connected by flexible ligaments, allowing the mouth to open to a very wide angle. In fact, a snake can open its jaws up to about 160°, compared to approximately 26° in humans.

b. Fangs

Some snake species have developed the capacity to inject venom into their prey in order to overpower it. This venom is delivered through specialized fangs and can immobilize or kill the prey. Although snakes are commonly linked with venom, only around 7% of species produce venom that is dangerous to humans. In venomous snakes, the fangs are hollow and attached to venom glands situated within the head. When the snake bites, these glands secrete venom, which flows through the hollow fangs into the victim.

c. Teeth

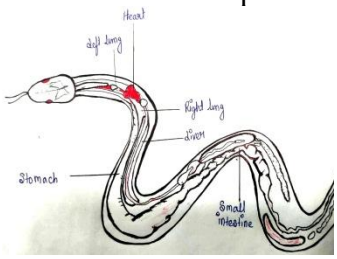
All snakes have special teeth. Since snakes swallow their prey whole, they need a strong grip to hold it. Their teeth are small, sharp, and curved backward. This backward curve helps hold the prey tightly and prevents it from escaping.

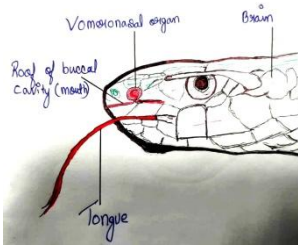
d. Vertebrae

Snakes do not have arms or legs and have long, thin bodies because of their special skeleton. Like other vertebrates, they have a backbone made of many small bones called vertebrae. Snakes have between 100 and 450. Each vertebra allows a small amount of movement, and because they have so many, snakes are very flexible and can bend easily.

e. Ribs

Each vertebra in a snake has two ribs attached to it. So, if a snake has 200 vertebrae, it will have about 400 ribs. These many ribs support the snake's long body and help keep it firm and strong while moving (Maxwell, 2023). These ribs are slightly flexible, which helps the prey move through the snake's body after it is swallowed. The organs inside the snake are long and narrow so they can fit into its thin body. Snakes move in different ways, such as slithering, sidewinding, and an accordion-like movement that helps them climb (Divers, 2024).





2. Internal body structure

a. Oral cavity

The tongue lies at the front of the mouth and can come out even when the mouth is closed. It is forked and helps the snake collect smell particles from the air. These smell particles are then passed to a special organ in the roof of the mouth called the vomeronasal organ, which sends signals to the brain to help the snake detect scents and pheromones. The mouth has salivary glands that produce saliva during feeding, but it is usually dry at other times. The throat leads to the oesophagus, a stretchy muscular tube that runs along the body and carries food to the stomach.

b. Stomach, associated organs and intestine

The snake's stomach is long and tube-shaped. It produces strong acid and digestive juices to break down food. Most digestion happens in the stomach and then continues in the small intestine. Parts of the prey that cannot be digested, such as hair, are passed out in the waste. The stomach opens into the small intestine. Near this area are the spleen, pancreas, and gall bladder. In some snakes, the spleen and pancreas are joined together. The liver is long and extends along much of the body. The small intestine connects to the large intestine, which is wider. In some snakes, a small pouch called the caecum is present at this junction. The large intestine empties into the cloaca, which is a common opening for the digestive, urinary, and reproductive systems.

c. Heart

A snake's heart has three chambers - two upper chambers (atria) and one lower chamber (ventricle). Even though it has three chambers, it works almost like a four-chambered heart. The heart is covered by a thin protective sac called the pericardium. It is located in the front part of the body and can move slightly, which helps when large food passes through the food pipe above it. Blood enters the heart through two veins from the front of the body and one vein from the back. These veins open into a small chamber called the sinus venosus, which then sends blood into the right atrium.

3. Sensory organs

a. Eye

Snakes do not have eyelids. Their eyes are covered by a clear protective scale that is shed with the skin. Day-active snakes usually have round pupils, while night-active snakes have slit-shaped pupils that open in the dark and close in bright light. Burrowing snakes have very small eyes, sometimes covered by skin or scales. Tree-dwelling snakes have larger side-placed eyes that help them see around them.

b. Ear

Snakes do not have external ears. They hear mainly through vibrations that travel through the bones of their skull. Although they lack visible ears, they still have small inner ear parts that help them detect ground vibrations and some low-frequency sounds.

c. Jacobson's organ and mouth

Jacobson's organ is located in the roof of a snake's mouth and helps detect very small amounts of chemical substances. These chemicals are collected by the forked tongue and then transferred to the organ for analysis. This structure is highly important and is present in all snake species. It plays a key role in tracking and identifying prey, detecting predators, following other snakes of the same species, and during courtship (Peters and Wallach, 2026).

d. Skin

In snakes, the outer skin forms scales that cover the entire body. Smaller scales are present on the head, while larger ones cover the body. Some scales are ridged for better grip, whereas others are smooth. The skin has few glands and a thick, keratinised outer layer made of dead cells. On the underside, a single row of broad ventral scales (scutes) runs across the body, each overlapping the next.

4. Different body systems

a. Respiratory system

Snakes have paired nostrils that open into the roof of the mouth. Unlike crocodiles, they do not have a hard palate. When the mouth is closed, the internal nostrils lie just above the tracheal opening, called the glottis, which remains closed except during breathing. The glottis leads to the trachea, supported by C-shaped cartilages. When a snake forcefully pushes out air, a small cartilage near the glottis vibrates, producing the characteristic hissing sound (Maders, 2011). The rigid glottal tube allows the snake to breathe even while swallowing large prey. In most colubrid snakes and some vipers, the right lung is well developed, while the left lung is reduced or vestigial, sometimes forming an air sac that may assist in gas exchange. In more primitive snakes like boas, both lungs are functional. The trachea divides near the heart, and the lungs extend along the front half of the middle third of the body. Snakes do not have a diaphragm. Breathing occurs through movement of the ribs and intercostal muscles, along with the elastic recoil of the lungs. Some snakes also have a "tracheal lung," which helps in breathing when the main lungs are compressed during swallowing. In snakes, breathing is mainly triggered by low oxygen levels rather than high carbon dioxide levels, unlike in mammals.

b. Musculoskeletal system

The skull of a snake contains a relatively small cranial cavity for the brain and a large nasal cavity. The maxilla typically bears four rows of teeth (two on each side), while the

mandible has two rows. Tooth structure varies among species. Non-venomous snakes, such as colubrids and boids, possess simple, backward-curved teeth. In contrast, venomous species show specialized adaptations; for example, rattlesnakes have hinged fangs that swing forward during a strike. All teeth, including fangs, are continuously replaced throughout life. The snake's skull is highly adapted for swallowing large prey. The two halves of the lower jaw are loosely connected and can separate at the mandibular symphysis. Snakes lack a true temporomandibular joint; instead, a movable quadrate bone connects the lower jaw to the skull, allowing wide expansion of the mouth. The maxilla is also loosely attached, increasing the oral opening. The skull articulates with the atlas vertebra through a single occipital condyle. Caudal vertebrae lack ribs and possess haemal processes that protect the coccygeal blood vessels. The ventral scales (scutes) cover strong segmental muscles supplied by intervertebral nerves. Coordinated contraction of these muscles, together with friction from the scutes, enables locomotion. In a few species, such as the glass snake, tail autotomy occurs, allowing the tail to detach and later regenerate.

c. Urinary system

Snakes have two long kidneys located in the back part of the body, attached to the upper body wall. The right kidney is placed slightly in front of the left one. Each kidney has a tube called a ureter that carries urine to the cloaca. Snakes do not have a urinary bladder. In male snakes, the back part of the kidneys becomes larger during the breeding season and helps in producing seminal fluid.

d. Reproductive system

i. Male

The paired testes of snakes are located within the coelomic cavity, positioned cranial to the kidneys, with the right testis slightly anterior to the left. They enlarge during the breeding season. Each testis connects to a vas deferens that opens into the cloaca, where seminal fluids are added. Male snakes possess paired copulatory organs called hemipenes in the tail. These remain inverted at rest but evert during mating. The hemipenes contain a groove that guides sperm into the female cloaca and are used only for reproduction, not urination.

ii. Female

Female snakes have two ovaries located in the front part of the body, with the right one slightly ahead of the left. Each ovary is connected to a long, coiled tube called the oviduct. The oviduct carries the eggs through different sections, including the uterus, before they pass through the vagina and into the cloaca. Blood supply to the oviduct comes from tissues attached along the back body wall. Most female snakes breed in spring when the weather becomes warm and days are longer, though some tropical species breed during cooler months. Some snakes lay eggs (oviparous), while others give birth to live young (viviparous). Certain species build nests, and some pythons keep their eggs warm by contracting their muscles to produce heat.

Conclusion

Snakes have a special body structure that helps them survive in many different environments. Even though there are thousands of species, their basic body design is almost the same. Their flexible backbone, wide-opening jaws, sharp backward-curved teeth, and strong muscles help them move easily and swallow prey whole. Their senses, breathing system, and reproductive organs are also well adapted to their way of life. Overall, snakes are highly adapted reptiles, and their body structure shows how well they have evolved to live successfully in nature.

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