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## REPTILE BASICS: CLINICAL ANATOMY 101

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A basic familiarity with reptilian anatomy is a prerequisite to understanding physiological and disease processes. Reptiles come in all sizes and shapes, but the basic body plan is the same as in higher vertebrates. A complete physical examination should be conducted in a thorough and methodical fashion. This article is an admittedly brief overview of some of the unique reptilian anatomic features.

### THE SKIN

The skin of reptiles lacks hair or feathers, and is devoid of follicles. Instead, adjoining or overlapping scales or *scutes* cover the reptilian body. The skin consists of a relatively thin epidermis overlying a thick dermis. There is no adipose tissue in the hypodermis, and the dermis is almost always immediately overlying subjacent muscle or bone. The alpha-keratins found in the reptilian integument are similar to those found in mammalian and avian skin, but reptiles also have beta-keratins that make up the hard, inflexible keratinous structures.

The distribution and arrangement of scales over the body are remarkably consistent within species and are often used as reptile identification keys. Over the course of their evolution, chelonians have developed a shell formed by a widened and fused dorsal (carapace) and ventral (plastron) rib cage connected by the bridges on either side, and have internalized the thoracic and pelvic girdle. This bony shell is covered by a thin but extremely dense and tough dermis and epidermis arranged in scutes. Carapacial scutes include the marginals, costals (pleurals), and vertebrales, and the paired plastral scutes are, from cranial to caudal, the gulars, humerals, pectorals, abdominals, femorals, and anals. The head and limbs of chelonians are covered with a smoother, sometimes scaled skin. In crocodylians, as well as in some chelonians and some lizards, small to relatively large dermal bones called osteoderms are present for added protection. In the squamates (lizards and snakes), true scales cover the whole body. There is an array of shape and size of these scales depending on the reptile species and the anatomic location.

There are very few cutaneous glands in reptiles, except for structures called pores (eg, pre- or post-anal pores, femoral pores) that are typically better developed in males and are used for scent-marking. The coloration of reptiles can be quite spectacular, and neurohormonal cues may result in dramatic changes in coloration, as in chameleons. This is due to the presence of chromatophores, or pigment cells, arranged in layers in the superficial dermis just beneath the basement membrane of the thin epidermis. These cells have cytoplasmic extensions through which they move pigments in and out of the basal layers of the epidermis.

Chromatophores are of different types: melanophores contain melanin (black or brown pigments), erythrophores contain erythrins and other red pigments, xanthophores contain yellow xanthins or carotene pigments, and guanophores or iridophores contain a variety of iridescent pigments. Albino animals, lacking melanin, may still be colored with yellow or other pigments, and therefore are not necessarily white. They are called hypomelanistic, or leucistic. Animals lacking red pigment cells, or erythrophores, are referred to as being anerythristic, and so on..... This is a dream come true for herpetoculturists who just love to select and breed color mutants that may look very different from the “wild” color prototype (eg, albino Burmese python, anerythristic corn snake). Herpetoculturists may give such color mutants a promotional name (eg, jungle beauty, arctic ball python) and sell them for a higher price. In many lizards, skin coloration may become darker if the animal becomes sick, and therefore it may be wise to recommend a physical examination in animals that suddenly darken for no obvious reason. In chameleons and some other species, coloration may vary with fear, excitement, hormonal status, gravidity, hierarchic position, and so on.

All reptiles undergo shedding of the skin or scales/scutes, a process called *ecdysis*. This process is rather subtle and continuous in crocodylians and in chelonians, but is periodical in lizards and snakes. In these animals, a cleavage zone develops between the old and the new growing epidermal stratum corneum. Lymph, or exuvial fluid, infiltrates the cleavage zone and the old corneum is sloughed. In snakes, the sloughing starts at the rostrum, and the animal literally crawls out of its own skin, leaving an epidermal cast called an exuvium (plural: exuvia). The skin and the spectacles turn a bluish opaque color from the exuvial fluid in the days prior (snakes) or immediately (geckoes) prior to ecdysis. Snakes that are about to undergo ecdysis are in a “blue” or “opaque” phase. The ecdysis in lizards is more sudden and explosive, with the old epidermis suddenly lifting, splitting and sloughing. Often, lizards will consume their exuvia. Impression smears and biopsies are useful diagnostic tools when confronted with cutaneous lesions.

Subcutaneous injections are easily administered in most reptiles. In chameleons, the skin may temporarily turn black following the injection. Fluids may also be administered epicoelomically in turtles: the needle is inserted below one front limb in the space between the coelomic wall and the plastron. Fluids may be given intracoelomically, but care should be taken to avoid the urinary bladder in species that possess one.

### THE MYOSKELETAL SYSTEM

All chelonians and crocodylians are quadrupedal, but within the order Squamata there are differences between the saurians and ophidians. Although all snakes are limbless, the more primitive species have retained a vestigial pelvic girdle and the vestigial pelvic limbs end in mobile spurs on each side of the vent, used in courting and mating. Leglessness is not restricted to snakes, as

many lizard species have evolved to lose their limbs. Glass lizards and worm lizards are good examples, and are easily identified as lizards by the presence of external ears and a fleshy tongue. In some lizard species, notably skinks, the legs may be greatly reduced in size and in function.

Chelonians have a carapace that consists of fused, flattened ribs and to which the thoracic and lumbar spine is fused, and a fused flattened sternum called the plastron. The plastron and carapace are connected on either side by the bridges. The head and limbs may be retracted into the shell for protection, and the plastron may be hinged to allow for complete closure of the shell, like in box turtles. In hingeback tortoises, the carapace is hinged at the caudal third of the carapace allowing for complete closure of the caudal half of the shell. The neck is flexible and retractable by means of powerful cervical muscles attached to the internal surface of the carapace. In the so-called side-necked turtles, the neck is not pulled inside the shell but actually folded sideways, under the leading edge of the carapace. The thoracic and pelvic girdles in chelonians have, over the course of evolution, found their way inside the rib cage, itself modified into a shell. The scapulae and ilia act as struts strengthening the shell, and are easily visible on radiographs

Crocodylians and lizards are roughly similar in their skeletal conformation to the quadrupedal mammals.

The body of snake is elongated and amazingly flexible. The spine consists of up to 400 vertebrae, depending on the species. A pair of ribs is attached to each vertebra, other than the coccygeal or caudal vertebrae. The skull of snakes is such that they may move each maxilla and mandible separately onto a prey item. They may disarticulate their mandibles to allow for the passage of a large prey.

Intramuscular injections are given in the appendicular muscle mass of chelonians, crocodylians, and lizards, and in the epaxial muscle mass of snakes. Intraosseous access may be achieved in the femurs of limbed reptiles, and in the bridges of the chelonian shell.

### **THE CARDIOVASCULAR SYSTEM**

All reptiles possess a double (systemic and pulmonary) circulation and a three-chambered heart that consists of one spongy ventricle and two large atria. In crocodylians there is almost complete partitioning of the ventricle by a median septum, and they are sometimes referred to as four-chambered heart animals. In the remainder of reptiles, vascular channels and ventricular anatomy is such that venous blood carried to the heart is directed to the lungs, and oxygenated blood return from the lungs is channeled through the left and right aortas, which meet caudally to form the dorsal aorta. This system is quite efficient and there is minimal mixing of venous and arterial blood in the heart, in spite of the single ventricle. The heart of most lizards is located quite cranially in the coelomic cavity, almost between the shoulders. The vascular tree is similar to that of the higher vertebrates, but the presence of a renal portal system sets reptiles (and birds, amphibians and fish)

apart from the mammals. The renal portal system is a network of vessels around the kidney, culminating in venules that wrap around the tubules of nephrons, through which the venous return from the caudal half of the body may be channeled or diverted under neurohormonal control, and depending on the physiological state and activity level of the individual reptile. Because of the presence of this renal portal system, it has long been argued that drug injections should be administered in the cranial half of the reptile patient, to avoid first-time passage through the kidney prior to reaching systemic circulation, and to minimize potential drug nephrotoxicity. This is debatable in view of recent research, but by tradition most clinicians will inject reptiles in anterior muscle groups.

Collection of blood from chelonians is easily performed from the subcarapacial sinus. Other sites include the jugulars, the supracaudal vein, the ventral coccygeal vein, and the humeral plexus. Lymph contamination may occur at any site, but is less likely with jugular venipuncture. The ventral coccygeal vein and the occipital sinus are the preferred sites in crocodylians. The ventral coccygeal vein is accessible in most lizards, and may be used in snakes. Palatine veins are accessible in the larger snakes but hemostasis is slow following venipuncture. Blood can be collected from the heart in snakes, but the procedure carries a risk of hemopericardium and tamponade. Indwelling intravenous catheters are inserted in the jugular of chelonians. A technique is described for jugular catheterization of snakes and iguanas. In the larger lizards, the ventral coccygeal vein may also be used for catheters.

### **THE RESPIRATORY SYSTEM**

In crocodylians, a sheet of non-muscular connective tissue analogous to a rudimentary diaphragm roughly separates the coelom into a thoracic and an abdominal cavity. All other reptiles have one continuous coelomic cavity. The lungs of reptiles are simpler than in birds or mammals. They are more or less paired blind-ended sacs whose lining is thrown in capillary-rich septa or folds that create roughly hexagonal spaces, somewhat like a ruminant's reticulum. These folds act to increase the gas-blood surface, and create infundibula, which are themselves subdivided in faveoli at the surface of which capillaries run and gas exchange occurs. Of course, there is quite the variation on this theme, and some reptiles such as crocodylians, monitor lizards, or chameleons have more intricate lung parenchyma. The lungs of reptiles are extremely expansible, and many lizards will puff themselves up, making them look bigger to would-be predators, by inflating their lungs to maximal capacity.

In snakes, there is a single elongated right lung, as the left lung disappeared through the course of their evolution. The boids (boas and pythons) are again an exception to the rule as they possess a vestigial, much smaller left lung. In some snakes and in crocodylians, the lung is sometimes prolonged caudally in a non-respiratory air sac, which serves as an air reservoir,

especially in aquatic species. The glottis in reptiles is practically always very rostral, just behind the tongue and is easily accessible for intubation. A palatal valve is present in crocodylians and needs to be pulled down to visualize the glottis. This valve allows for sealing of the throat opening when the animal is submerged. The trachea of snakes is long, but that of some chelonian species bifurcates rather early, and care must be taken not to push the endotracheal tube too far into one bronchus. The rings are complete in turtles and crocodylians. In snakes, the tracheal mucosa is capable of limited oxygen exchange, a possible adaptation to a prey item slowly moving down the esophagus, temporarily compressing the lung. In some aquatic turtles, oxygen may be extracted from water through the cloacal mucosa!

Lung washes are easy to perform in reptiles, but may require anesthesia. Nebulization and intrapulmonary instillation of medication may also be performed.

### THE DIGESTIVE SYSTEM

There is little variation among reptiles as to the components of the digestive system. The oral cavity opens into a usually large pharynx, an esophagus, a stomach, a small and large intestine, a more or less developed caecum, and a cloaca. All reptiles have teeth except for chelonians, in which the tough and razor-sharp keratinous tomial edges of the maxilla and mandibles act to cut vegetation or prey.

Many species of snakes, referred to as venomous snakes, kill their prey by injecting potent venom into their victim. The venom is usually a complex mixture of enzymes and toxins. While the venom of a snake maybe called neurotoxic or cytotoxic, it typically is a combination of both. Venom glands of most venomous snakes are modified salivary glands, but venomous colubrids possess paired venom-secreting Duvernoy's gland, separate from their salivary gland. Venom glands open in the mouth, where the venom is channeled into the prey by specialized teeth called fangs. Non-venomous snakes are referred to as aglyphs. By far most colubrids are non-venomous, but some are, notably the boomslang. Venomous colubrids are rear-fanged (opistholyph) and deliver venom through a pair of grooved rear teeth (or fangs). Venom is delivered through fixed front teeth (proterolyphs) in cobras and other elapids, and in the more evolved species through hinged moveable hollow fangs that act in the same way as hypodermic needles (solenolyphs: crotalids and viperids).

Gila monsters and Mexican beaded lizards are venomous lizards that literally chew their venom into the victim. The tongue of crocodylians is rudimentary. That of turtles and lizards is typically fleshy, mobile, and sticky, and is protruded from the mouth toprehend food or catch insects. This reaches a maximum in chameleons, which can literally project onto unsuspecting insects the sticky tip of their long tongues at a distance that exceeds their total body length. In these animals, the tongue is folded over the median hyoid bone called the entoglossal bone, much in the manner of a stocking.

When a prey is spotted, the chameleon anchors itself with its prehensile tail, raises its entoglossal bone, and aims. A powerful sphincter called the accelerator muscle squeezes the tongue tip against the bone, projecting it into the distance much like a hand squeezing a bar of soap, and then the overstretched retractor muscle coils back to bring the tongue back in. The tongue of snakes serves a sensory purpose. It is retracted in a sheath located below the glottis and is rhythmically extruded and flicked out of the mouth through a small aperture called the lingual fossa. Monitor lizards and tegus flick their tongues in a similar way.

The pharynx of reptiles is relatively wide, allowing for the passage of large food items. The stomach is large and typically quite distensible. In crocodylians, it consists of two parts, a large and muscular fundic part, sometimes called a gizzard, and a smaller pyloric part opening into the duodenum. In carnivorous species, the intestinal tract is short and simple. All herbivorous reptiles are hindgut, typically colonic fermenters. The cloaca terminates in the anus, referred externally as the vent.

The liver of reptiles is well developed. In snakes, it is an elongated structure that lies ventral to the caudal two-thirds of the lung and ends at the stomach. Interestingly, the gallbladder of snakes is located distal to the stomach. Snakes have a discrete roundish structure just distal to the stomach that combines pancreatic and splenic tissue and is called a splenopancreas. Oral administration of medications may be a frustrating exercise in turtles, but esophagostomy tubes allow for medicating and provision of nutritional support. Medication can be inserted in prey items for carnivorous species. Most small lizards may be tube-fed if necessary.

### THE UROGENITAL SYSTEM

Reptiles are uricotelic, which means they excrete uric acid as the end product of protein catabolism, as opposed to ammonia or urea. Some highly aquatic reptiles are partly ureotelic. Reptiles have paired kidneys, located in the caudal coelomic cavity, that communicate with the cloaca via the ureters. They do not have a urethra. In the green iguana, and many other iguanids, the kidneys are actually located under the roof of the pelvic canal, so that disease leading to swelling/enlargement of the kidneys in these animals may translate clinically in constipation, from their impingement on the lumen of the canal. In snakes, the kidneys are thin and elongated structures along the caudal digestive tract, and in these animals the left kidney is cranial to the right one. A urinary bladder is present in all chelonians and in most lizards as an outpouching of the cloaca. Some lizard species, as well as all snakes and crocodylians, lack a urinary bladder. In turtles and tortoise, the urinary bladder is particularly large and very thin-walled, and serves mostly to store water and electrolytes.

In all reptiles, gonads are paired and internal and communicate with the cloaca via the vas deferens or the oviducts. All male reptiles also have grooved intromittent

copulatory structures that are inserted in the female's cloaca at mating and serve to guide the sperm. Crocodylian and chelonian males possess a single, median structure called a phallus, which lies on the cloacal floor at rest. Squamates (lizards and snakes) have paired structures called hemipenes (plural of hemipenis), which at rest lie invaginated within the hemipenal pockets, distal to the vent. Upon becoming engorged and turgid, the hemipenes are everted and extruded out openings that lie just lateral to the anus. The retractor muscle attached to the deep end of the hemipenal pocket becomes stretched and pulls the hemipenis back when the turgor resolves. Hemipenes are used in an alternate fashion, and one may be slightly larger than the other.

All crocodylians and all chelonians, as well as most squamates, lay eggs. Some snakes such as boas and rattlesnakes are live-bearers. Some lizards are also live-bearers, the best example being Jackson's chameleons, but even within the Chameleonidae family, most species are egg layers (e.g., veiled and panther chameleons). Eggs are typically buried in soil or sand.

#### **THE IMMUNE SYSTEM**

Reptiles do not have lymph nodes. They have all the components of the humoral and cell-mediated immune system of higher vertebrates. Lymphopoiesis and hemopoiesis occurs in the bone marrow, spleen, and at other extramedullary sites scattered in the body. The thymus regresses with age. Lymphoid tissue is present in the submucosa along the digestive and respiratory tracts.

#### **THE NERVOUS SYSTEM AND THE SENSES**

The lissencephalic reptile brain is encased in a solid skull and the spinal cord is also well protected within the spinal column. Reptiles have a diencephalic brain, and the complete set of 12 cranial nerves present in birds and mammals. The acuity of the various senses is variable among reptile taxa. Hearing is poor in reptiles, and absent in snakes, which are earless. Snakes and other reptiles, on the other hand, can easily detect vibrations in the ground. Nothing is known of the sense of taste in reptiles, but it is likely very poor. The eyes are well developed in most pet reptile species. Scleral ossicles are present and moveable eyelids are the rule, but in snakes the eye is covered by a modified, transparent scute called the spectacle or eyecap. Most geckos do not have moveable eyelids and keep their corneas moist by licking them regularly. Eyesight is well developed in chelonians, crocodylians, and lizards, but as a rule is limited in snakes, which are assisted by an incredible sense of smell. Scent particles on the tongue are detected when animal inserts each of the tongue's forks against their respective small palatal openings leading to the Jacobson's organ. In turn, the Jacobson's organ's olfactory nerve terminations forward the information to the brain, where it is processed. Many snakes such as boids and pit vipers are also equipped with thermosensitive heat-pits that pick up heat emission from potential prey.

Reptiles store fat in the form of paired abdominal (or coelomic) fat pads, although some species also store fat in their tails (crassicaudation). They do not store fat under their skin, as mammals and birds do. Fat pads are often prominent on abdominal palpation and should not be mistaken for abnormal structures.

This article provides a very basic introduction to the anatomy of reptiles. Excellent herpetology books are available to further the knowledge of interested readers.