HERPETOLOGY

CHAPTER GOALS

- Know the common characteristics of amphibians and reptiles, and distinguish them from other vertebrates.
- Outline the natural history and diversity of amphibians and reptiles in Kansas.
- Explain conservation issues relevant to Kansas herpetofauna.
- Gain an understanding of the role reptiles and amphibians play in the ecosystem.

A. Introduction

Kansas is home to 95 native species of amphibians and reptiles and three non-native species for a total of 98 species (see the end of this chapter for complete list).

The study of reptiles and amphibians is called Herpetology (the word comes from the Greek 'herpeton', meaning "creeping animal"). Although reptiles and amphibians differ greatly, we study them together for reasons of tradition and convenience. Similar techniques are used for finding and capturing members of both groups. In addition, they are often found in the same habitats. Most naturalists tend to be interested in both groups, and many prominent Kansas herpetologists have studied both amphibians and reptiles.

Amphibians and Reptile Species in Kansas

Group	Family	Species
Amphibians		
Frogs &Toads	5	21
Salamanders	4	9
Reptiles		
Lizards (native)	5	13
(non-native)	2	3
Snakes	5	39
Turtles	4	13

This chapter is designed to serve as a general introduction to herpetology for the naturalist in Kansas. The natural history of amphibian and reptile origins will be covered in order to place herps in proper evolutionary context. Sections on amphibian and reptile diversity focus on broad patterns and concepts that are central to the natural lives of herps, and the processes that have resulted in the diversity of herps in our state. Amphibians and reptiles together encompass enormous diversity; therefore it is not surprising that the processes that drive the diversity of salamanders, frogs, squamates (lizards and snakes), and turtles are different. Hopefully, the reader interested in herpetological natural history will be able to use this chapter as a guide for further study, not only of individual species, but also of higher taxonomic groups and herpetological communities.

B. Herpetology in Kansas

Kansas is a large state, measuring 211 miles from north to south and 417 miles from east to west. It also varies in rainfall from 45 inches per year in the southeastern corner to 15 inches per year in the northwest and possesses an interesting geological past, both of which lead to a variety of environmental conditions and habitats. Because of its size, location, and diverse habitats, Kansas is populated by a rich variety of reptiles and amphibians, numbering 98 species. This includes 9 species of salamanders, 21 frogs and toads, 13 turtles, 16 lizards (three non-native species) and 39 snakes.

Most of the original habitat within the state has been destroyed by man. During the last century, almost the entire original prairie was converted to agricultural fields. More recently, urban sprawl is eradicating what little habitat had been spared from agricultural use. Natural prairies, forests, river bottoms, and the like have been reduced to isolated habitats with few corridors for animals to use for safe passage between them. Nevertheless, reptile and amphibian distribution is determined by the location of current or former habitats.

There are only five species of venomous snakes within the state. The cottonmouth is rarely found, and only in the extreme southeastern corner of the state. The timber rattlesnake and the copperhead inhabit the eastern third of the state. The eastern massasauga is a small species of rattlesnake found in small numbers throughout the eastern 2/3 of the state. Theprairie rattlesnake is found in the western 1/2 of Kansas.

C. Common Characteristics of Amphibians & Reptiles

Amphibians and reptiles are not closely related, but they do share a few common characteristics. Both amphibians and reptiles possess Jacobsen's organ, a specialized olfactoryorgan in the roof of the mouth. Jacobsen's organ is highly developed in the lizards and snakes (squamates) that rely heavily on olfaction (smell) to sense their surroundings.

The tongue flicking behavior we notice in snakes and some lizards is used to collect molecules in the air or on the ground moving them into Jacobsen's organ where they can be analyzed. Herps also have a common opening to the digestive, reproductive, and urinary tracts called the cloaca.
All herps are **ectotherms**, meaning their temperature regulation depends on the environment, not metabolism, and many are also **poikilothermic**, meaning their temperature varies widely rather than remaining at a constant state. Almost all other animals (e.g., fish and insects) are also ectotherms, so this feature alone does not really unite amphibians and reptiles in the biological sense. Being ectothermic can be a disadvantage in some ways. For example, herps may be more vulnerable to predators and

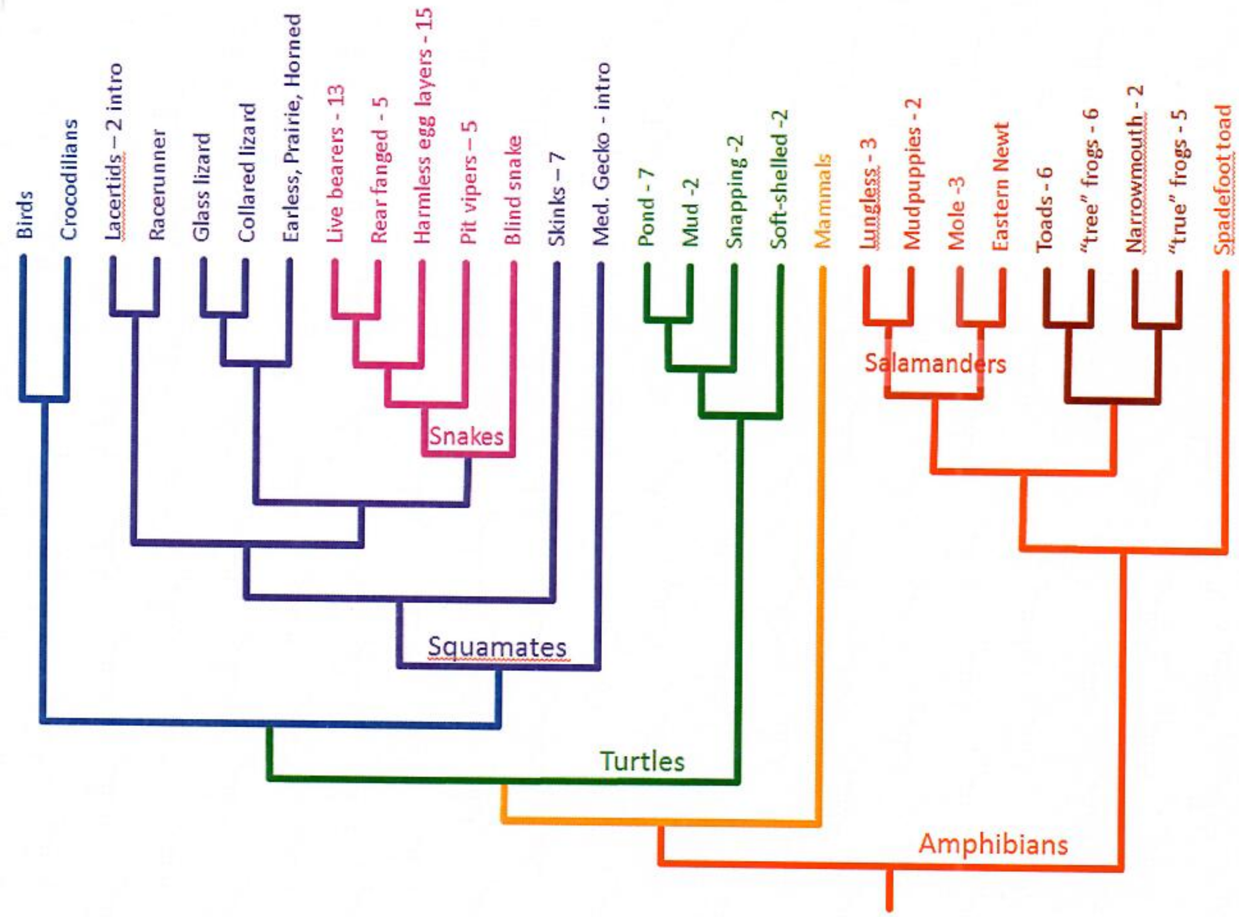
accidents when they are cold, and the distribution of herps is limited to relatively warm regions.

Ectothermy also has many advantages over endothermy (internal control of body temperature via metabolic processes), and is not inferior, or less advanced, than the endothermic metabolism of mammals and birds. Because of the low energy requirements of ectothermy, amphibians and reptiles can simply shut down when times are tough, such as when food is scarce or the climate is too cold, hot, or dry. Ectothermy may also explain why there are so many small-bodied and elongated species of herps compared to mammals and birds. The high metabolic costs of endothermy are the reason there are few long-bodied mammals like weasels and ferrets, and none smaller than shrews. Ectothermic metabolism does not constrain the evolution of small body size or the evolution of the elongated body forms that are so common in snakes and lizards

D. The Relationships of Amphibians & Reptiles to Other Vertebrates

The fundamental common feature of amphibians and reptiles, and the one they share with other terrestrial vertebrates, is their **tetrapod** (tetra = 4; pod = legs) origin. The characteristic of four limbs arose with the common ancestor of all terrestrial vertebrates, and along with mammals and birds, herps are classified as tetrapods. Even snakes and some lizards and salamanders are "limbless tetrapods" because loss of limbs in these groups is a condition derived from their fully-limbed ancestors.

By tradition, we discuss birds at the level of class, but by doing so we obscure their close relationships to crocodilians. The lineages of reptiles, including birds, are much more closely related to each other than to the amphibians, with which they have not shared a common ancestor in 300 million years. Below is a phylogenetic tree illustrating the evolutionary relationships of the tetrapods. The amphibian and reptile groups found in Kansas are included. Numbers indicate how many species of that particular group are found in Kansas. Those without numbers are groups represented in Kansas by the single (or several) species listed. The notation "intro" means those species are introduced and not native to Kansas. So, there are 4 species of lungless salamanders in Kansas and 2 species of Lacertid lizards (both of which were introduced.


Birds
Crocodilians
Lacertids – 2 intro
Racerunner
Glass lizard
Collared lizard
Earless, Prairie, Horned
Live bearers - 13
Rear fanged - 5
Harmless egg layers - 15
Pit vipers – 5
Blind snake
Skinks – 7
Med. Gecko - intro
Pond - 7
Mud -2
Snapping -2
Soft-shelled -2
Mammals
Lungless - 3
Mudpuppies - 2
Mole -3
Eastern Newt
Toads - 6
"tree" frogs - 6
Narrowmouth - 2
"true" frogs - 5
Spadefoot toad
Salamanders
Snakes
Squamates
Turtles
Amphibians

E. NATURAL HISTORY AND THE DIVERSITY OF AMPHIBIANS

There are more than 7,000 species of extant amphibians (see Amphibiaweb.org for updated species counts) in three orders: salamanders (Caudata), frogs (Anura), and caecilians (Apoda). Caecilians are worm-like amphibians that inhabit tropical regions of the world. Amphibians as a Class share a few common natural history features, such as metamorphosis from larval form to adult form, and relatively permeable skin with mucous (secrete fluids to keep skin moist and protected) and granular glands (secrete toxins).

Development of granular glands varies among groups, but most amphibians are capable of producing at least some toxic skin secretions. In some groups, such as newts and toads, toxins are very poisonous. It is clear that in combination with defensive behaviors, toxic skin secretions serve to deter predators. Amphibians also have a strong dependence on moist microhabitats compared to other terrestrial vertebrate classes. Amphibians do not have claws, true nails, or scales. Gas exchange may occur via lungs, gills, or the skin. Lungs are completely absent in salamanders of the family Plethodontidae. The skin is also important for water absorption. Many frogs, for example, have patches on their lower abdomen that are used to uptake water. Amphibians have a tympanum (eardrum) that allows hearing in the air, and a well-developed olfactory epithelium that permits them to detect odors.

The tympanum is the eardrum of a frog and in some species (like this bullfrog), it can be seen very clearly.

Amphibians occur everywhere except Antarctica, extreme northern parts of Europe, Asia, and North America, and most oceanic islands.In Kansas, amphibians occur statewide in virtually all habitats, including the driest and hottest parts.

In the following sections we will see how the natural history of amphibians helps explain their diversity. Variations in life cycles, the ecology of amphibian larvae, patterns of development from egg to adult, and species isolating mechanisms all contribute to this diversity.

1. Diversity of Amphibian Lifestyles: Life Cycles, Ecology, and Development

Life History Strategies

Amphibian life cycles can be thought of as a game with a few key pieces that can be tinkered with to accomplish different "life history strategies." A few important components of the amphibian life history game are larval period (time spent as a tadpole or salamander larva), terrestrial period (time spent living on land), and when, where, and how many eggs are laid. Individuals play their own life history game, in an evolutionary sense, to maximize chances for survival and reproduction in the environments where they live. The result being that each species, and sometimes populations of a single species, ends up with a characteristic life history. Amphibian life histories are varied and sometimes amazing; it is not surprising the life cycles of amphibians are often the principal point of interest for naturalists.

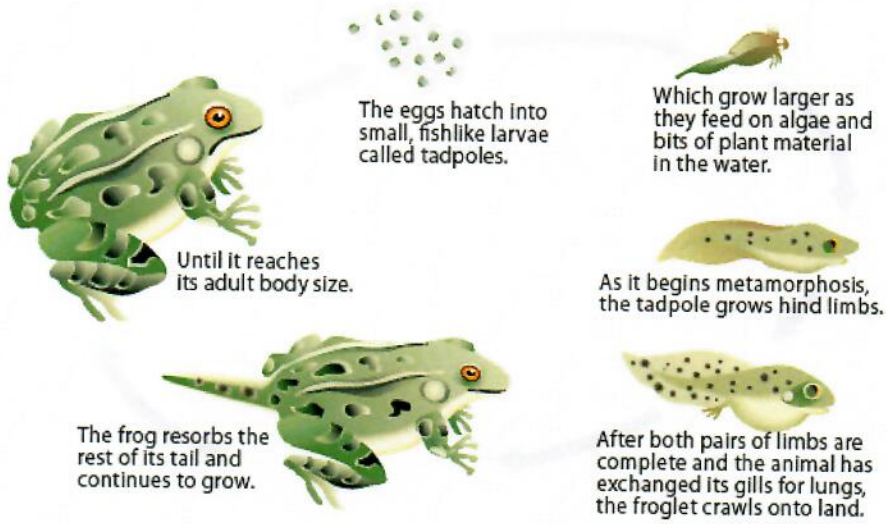


Diagram courtesy of www.ifrog.us

Although the life cycle characterized as egg-larva-adult is considered typical for amphibians, the life history game has been played so many different ways that there is actually a complete gradient in amphibian life histories. In fact, only 20%-25% of salamander species have this "typical" life cycle. Instead, most salamanders deposit a few eggs in moist microhabitats, care for them, and the eggs hatch into fully formed juveniles. Most frog species lay large numbers of eggs in water, and aquatic tadpoles metamorphose into adults. The length of time spent in the tadpole stage is highly variable, however. In some environments, it pays to devote time and energy into the larval stage, and less time into living and growing as a terrestrial frog. In other circumstances, the aquatic environment may be undependable or risky, in which case it pays to shorten the tadpole stage and get on with life as a frog.

Variations on this theme characterize the different salamander and frog families. True frogs (Ranidae) have highly aquatic tadpoles that take several months or up to more than a year before metamorphosing into juveniles. Toads (Bufonidae) and tree frogs (Hylidae) have much shorter larval periods, usually metamorphosing within a few weeks to several months. In contrast are the spadefoots (Scaphiopodidae), known for their explosive breeding aggregations and extremely short larval period. The eastern spadefoot may aestivate (a short term version of hibernation) underground for up to a year waiting for

rains. When sufficient rain falls, the spadefoots emerge and breed during one or two nights, in temporary pools and flooded fields. Their super-active tadpoles grow and achieve metamorphosis in as few as 14 days. The barking frogs (Eleutherodactylus augusti) of Texas and New Mexico, have arrived at the extreme end of the aquatic-terrestrial gradient. Like other members of their genus, they completely bypass the tadpole stage. Their eggs are laid in humid microhabitats and develop directly into miniature froglets. The adaptation of direct development frees barking frogs from dependence on standing water for reproduction, and aids their existence in dry climates.

Salamanders also have highly evolved life history strategies and many of those strategies are represented in the groups of salamanders found in Kansas. Mole salamanders have aquatic larvae and terrestrial (burrowing) adults, mudpuppies are aquatic throughout all life stages and lungless salamanders are all terrestrial with direct development and no larval stage. Newts are aquatic as adults and courtship occurs in the water. Their larvae either metamorphose into into something called an eft that leads a terrestrial life for several years, then returns to the water, or they may skip the eft stage entirely and metamorphose into aquatic adults. Depending on environmental circumstances, there are apparently tradeoffs that benefit or hinder survival as efts or larvae.

Larval Ecology

Many frogs and salamanders spend a significant portion of their lives as aquatic larvae.. Amphibian larvae live in communities, interacting with each other and with predators. The aquatic stage of many frogs is probably more significant to their overall life history than any other stage, inspiring tadpole ecologist, Richard Wassersug, to proclaim that frogs are merely packages used to transport the species' genes from pond to pond!

Frog tadpoles come in several basic types that show various modifications depending on the species. Regardless of the morphological type, tadpoles are primarily herbivorous, using various means to scrape or filter small bits of plant material and algae. Tadpoles in later stages of development tend to become opportunistic feeders and more omnivorous. Salamander larvae have external gills. They are opportunistic predators, feeding on a variety of prey including insects, crustaceans, and worms.

Differences in feeding mode result in amphibian larvae foraging in different places in a pond: for example in the water column, on standing aquatic vegetation, and on the bottom. Hence, there are a variety of ecological niches that are occupied by different frog and salamander larvae, and many possess feeding and swimming morphologies that are well suited to their lifestyles.

Amphibian larval ecology is predominated by two determining factors: whether or not they inhabit permanent or ephemeral water bodies, and the presence of predators. The common predators of amphibian larvae include predaceous beetle larvae, crayfish, some true bugs, dragonfly larvae, and fish. Mud turtles and garter snakes may also be important larval predators.

There are clear feedbacks between the life history strategies described above, risks of predation, and water permanency. Frogs that inhabit temporary pools are generally very active, eat a lot, grow fast, have short larval periods, and metamorphose into relatively small froglets and toadlets. These characteristics make them particularly vulnerable to terrestrial rather than aquatic predators. Tadpoles from more permanent water sources spend more time as tadpoles and are larger at metamorphosis, making them more vulnerable to aquatic rather than terrestrial predators.

2. Development and Species Divergence in Salamanders

Salamanders are a group of vertebrates that exhibit a high frequency of morphological divergence due to changes in the timing of development as they grow and metamorphose from larval to adult form. During growth from embryo to adult, different features grow at different times, and some features grow faster than others. Salamanders show a propensity for truncating the development of features. The development of head shape, mouth parts, and absorption of gill filaments, for example, may stop while the animal continues to grow and reach sexual maturity. The result is a salamander that retains larval characteristics as an adult.

In many cases, we know that truncated development has produced new kinds of salamanders that are very different from their ancestors. Even entire families of salamanders are characterized by their larva-like characteristics. Sirens, for example, have external gills, poorly developed limbs, and undeveloped mouth parts. These are all juvenile characteristics that have been retained in the adults. Similarly, Proteids, the family containing mudpuppies (Necturus maculosis) and some species of lungless salamanders and mole salamanders also exhibit larval characteristics that are explained by truncated development of the ancestral condition.

3. Species Isolating Mechanisms

Courtship & Species Divergence in Salamanders

Among salamander families, there is an interesting trend of increasing complexity in courtship and transfer of sperm from male to female. One of the most ancestral salamander families, Cryptobranchidae (Hellbender), has external fertilization.

The courtship of Sirens has never been observed, but their anatomy

suggests they also have external fertilization. All other salamanders have internal fertilization. Males produce a waxy structure with a cap of sperm called a spermatophore that is either introduced into the cloaca of a female or deposited on the substrate and picked up by the female. Males produce chemical cues that stimulate females to breed, and individuals respond to the chemical cues of their own species. Females have structures called spermatheca inside the cloaca that are designed to receive the spermatophore. Each species has distinctive male spermatophores that match the female spermatheca.

In the Salamandridae (newts) native to Kansas, males pursue and capture females with their hind limbs and rub the female's face with glands on their head to apply chemical stimulants. Usually the spermatophore is then deposited to be picked up by the female, but the male may also place it directly into her cloaca.

Mole salamanders (Ambystomatidae) also court in the water, where they then deposit the eggs, which are typically attached to submerged vegetation. Breeding pools are usually ephemeral, causing quick hatching and development to the more terrestrial adult stage. Male marbled salamanders (Ambystoma opacum) in Kansas lead females on a walk, fanning chemicals onto her snout with their tails. The female nudges the male causing him to deposit a spermatophore that she then picks up. Each female lays 100-300 eggs in a loose cluster on land in an area they know will eventually hold water. The eggs hatch when covered with water from autumn rains. Larvae transform the following April or May.

In the highly derived and speciose lungless salamanders (Plethodontidae), courtship is even more elaborate. Males lead females on a tail-straddling walk, where the female straddles the male's tail while resting her chin on his tail. This behavior is unique to the family. When the male deposits a spermatophore, he turns and blocks the walking female so that her cloaca is positioned precisely over the spermatophore that she then picks up. These movements are very precisely matched for body size among species and even populations. Experiments conducted on plethodontids showed that when individuals from populations with relatively large females were mated with small males from neighboring populations, there was a 25% decrease in successful spermatophore pickup. This implies that the mating system of these salamanders may not only keep salamanders of different species from hybridizing, but may also be a factor driving the morphological divergence between populations, and eventually speciation.

The courtship behaviors and mating systems of salamanders have clearly been important in generating and maintaining diversity in salamanders.

4. Frog Songs

Everyone has heard frogs croak, and naturalists quickly learn to identify frog species based on their calls. It does not take much experience to realize, however, that the natural history of frog vocalizations is exceedingly complex. In the cacophony of frog calls on a rainy night, how do the dozen or so species distinguish each other and find mates? Do males call only to attract females, or may their calls have other purposes?

In a few species, females give a call in response to the male's call, but females of most species do not call. Sound is produced when air passes over the vocal chords. Most male frogs also have vocal sacs that, when inflated, function as a resonator. Vocal sacs can be of different types depending on the species: a single large sac under the chin, paired sacs under the chin or paired lateral sacs that distend on either side of the head. The size of the frog and shape of the vocal sac influences the qualities of the call, whereas temperature, substrate, and vegetation affect how well the call is transmitted.

It turns out that each species of frog has a distinct set of calls. A large number of field and laboratory studies have revealed that, not only do males use courtship calls to attract females, but they also use other types of calls to defend territories and communicate with other males. Males in a breeding chorus continually assess their situation and vary their calls according to circumstances in order to save energy, or to increase their competitiveness against other males. Predators cue on frog calls; hence males are faced with the tradeoff of producing calls that are most attractive to females, or least noticeable to predators. Elegantly designed playback experiments, some accomplished in natural field conditions, indicate that chorusing frogs make these complicated decisions all the time. Males can assess the intensity of other males' calls and judge the distance between them. They can also gauge the body size of other calling males—an important piece of information, since large males usually win contests. It has even been shown that bullfrogs can identify other males individually.

Other experiments have shown that females in general prefer complex calls, but males may not expend the energy to produce the most attractive call unless motivated to do so by competing males. In isolation, male gray tree frogs and other hylids give a simple call, but when the density of males in the chorus increases, so does the complexity of their calls. When multiple males are advertising for females, they reduce overlap in their calls to avoid acoustic interference. This is the reason frogs commonly sing duets, alternating calls between individuals or even between species. Males can very rapidly adjust the timing of components of their calls, and instantly seize a moment of silence to insert a call into the chorus.

F. Natural History and the Diversity of Reptiles

In all there are more than 9,700 species of turtles (Testudinata), crocodilians (Crocodylia), squamates (Squamata), and tuataras (Rhyncocephalia, 1 species found only in New Zealand) that comprise the reptiles studied by herpetologists (see http://www.reptile-database.org/ for updates). Squamates include all the lizards and snakes; and as a group, share many features including a transverse cloacal slit, regular skin shedding, and paired copulatory organs in males (called hemipenes). Reptiles produce amniote eggs that, unlike amphibian eggs, have a set of three membranes surrounding the embryo that serve to collect waste (allantois), exchange gases with the environment (chorion), and cushion the embryo and prevent dehydration (amnion). A calcareous shell that can be either hard or leathery typically completes the package. Amniote eggs come in various forms, and many squamates retain eggs inside their bodies and give birth to live young. In these instances, eggs are not encased with a shell. All reptiles, with the exception of crocodilians and birds, have a 3-chambered heart with a single ventricle. Crocodilians, like birds and mammals, have a 4-chambered heart.

The basic tetrapod skeletal structure typifying most lizards has been variously modified in reptiles, allowing them to function well in different aquatic and terrestrial habitats. Limb loss is a recurring pattern in squamates. Several lizard families, including the Scincidae (skinks) and Anguidae (glass lizards) found in Kansas, exhibit varying degrees of reduced limbs or limblessness, depending on the species. All snakes in Kansas are completely limbless, but ancestral snakes retain vestiges of the pelvic girdle. Turtles are instantly recognizable because of their shell. The turtle shell consists of the vertebral column, ribs, and pelvic and pectoral girdles that are fused with dermal bone.

The internal organs of reptiles are typical of other vertebrates, and also show modifications, depending on the group. All reptiles have lungs and breathe air, and some aquatic turtles are also very good at aquatic respiration. Softshell turtles are particularly good at aquatic respiration, possessing specialized skin structures in the buccal cavity that aid gas exchange in water. Reptiles do not have a diaphragm to aid in filling the lungs as mammals do. Squamates pump air in and out of the lungs by expanding and contracting the sides of their bodies. This is not an option for turtles with their hard shell. Turtles breathe by flexing the shoulder and pelvic girdles that are connected to the lungs by membranes of connective tissue. For this reason, turtles cannot breathe when they are inside their shells. Internal organs of snakes are modified to accommodate their elongate body form and dietary habits. Only the right lung is developed in most snakes (the left lung is vestigial), and they have a long, and well developed stomach to accommodate their huge meals.

An interesting feature of most turtle families and several lizard families is their system of sex determination. In these reptiles, sex is not determined by by what genes are present, but by the temperature at which eggs are incubated. Temperature-dependent sex determination occurs after the first few weeks of incubation. In most turtles and lizards

with this kind of sex determination, high temperatures produce females, and low temperatures males. In some turtles, males are produced at intermediate temperatures, and females at more extreme high and low temperatures. Hence, the nesting environment and weather are the determining factors in producing males and females. Conservation biologists have taken advantage of temperature-dependent sex determination to propagate large numbers of female seaturtles and tortoises for restocking programs.

Reptiles are a large and diverse group and, like amphibians, are found almost everywhere. Kansas is a great place for appreciating and studying reptiles, and they can easily be found during any warm month of the year in virtually every corner of the state. The following section is primarily aimed at principal factors that have overwhelmingly influenced the natural lives of lizards and snakes: thermal regulation, foraging modes, and reproductive mode.

1. DIVERSITY OF LIZARDS AND SNAKES (SQUAMATES)

THERMAL REGULATION

As previously mentioned, all herps are ectotherms, and temperature is a central factor in the lives of most herps. Amphibians in the field have body temperatures that generally fall between 50° F (10° C) and 80.5°F (27° C), whereas lizard body temperatures are higher, ranging between 68° F (20° C) and 106° F (41 ° C). Stream salamanders and some nocturnal herps tend to have lower body temperatures in the field than species that live in hot places. Metabolism increases with body temperature up to a point, above which metabolic systems are compromised, and metabolic rate begins to crash. For most lizards, body temperatures above 108° F (42° C) are lethal after a few minutes.

Most naturalists have seen lizards and snakes basking on rocks and trees to warm themselves in the sun, often changing positions to maximize exposure. Physiological mechanisms that affect body temperature include shunting blood to or away from extremities to aid in heating or cooling, especially in large species. Changing colors affects absorption of heat, and it is common to see lizards that are particularly dark when they are cool. Squamates can also pant to get rid of heat-laden moisture from the lungs. Absorbing direct sunlight is only one means of elevating body temperatures. Reflected solar radiation, infrared radiation, and conduction of heat from the substrate all contribute energy that can raise body temperature. Evaporation, convection (carrying heat away in the wind), and heat radiated from the animal's body itself are ways that heat energy is lost. Behavior and physiology give squamates a lot of control over their temperature and metabolism. They readily achieve body temperatures that are higher or lower than the temperature of the surrounding environment. Hence, a basking lizard arrives at a momentary, delicate balance of all of these factors to achieve its body temperature. Environmental conditions change continuously with passing sun, clouds, and breezes, and so does the equation that determines body temperature.

Environmental conditions can limit daily activity patterns of lizards and snakes. In hot environments, diurnal lizards typically bask early to achieve their preferred temperature, are active in the morning, retreat into burrows or other shelter during the extreme hot parts of the day, and resume activity in late afternoon.

Temperature affects practically everything herps do, including how well they run and jump, digest their food, hear, see, defend themselves, and how long they may remain active. Lizards are able to run faster when body temperatures are close to their preferred range. Running speed and stamina are much reduced at temperatures outside this range. Snakes may shift their defensive behavior from fleeing at optimal body temperatures, to bluffing, striking, and biting at lower body temperatures. This may occur because, at low body temperatures, snakes will not be able to move as quickly and so, may have a better chance of defending itself by standing its ground.

2. Foraging Modes

(A) Sit and Wait Versus Active Foraging in Lizards

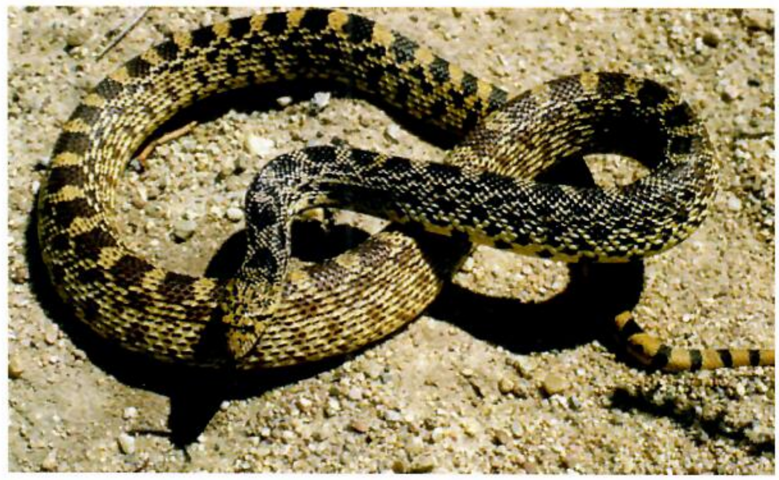
There are two extremes of foraging mode that squamates can use to find prey: actively seeking or waiting in ambush. Herpetologists have classified these two extremes as sit-and-wait versus active foraging. Because finding food is central to the lives of organisms, foraging mode carries with it consequences for almost everything else—energetics, morphology, behavior, predator avoidance, even aspects of thermal biology previously discussed. These two foraging modes are strongly tied to the major lineages of lizards.

The sit-and-wait mode is characteristic of the iguanian families Phrynosomatidae (like earless lizards), and Crotaphytidae (like collared lizards); whereas the families Teiidae (racerunners) and Scincidae (skinks) are active foragers. Typically, sit-and-wait foragers waitin ambush for insect prey, then dash out and seize it. Sit-and-wait foragers are visually oriented predators. They are good at sprinting for relatively short distances, and generally do not have as much stamina as active foragers. Sit-and-wait foragers rely more on cryptic coloration to avoid detection than active foragers that flee predators, and have striped or mottled patterns that are confusing when in motion.

Active foragers move quickly from patch to patch searching under leaf litter, poking into nooks and crannies, or chasing down prey. In general, active foragers have higher preferred body temperatures than sit-and-wait foragers. Active foragers also eat more prey to fulfill their energy budgets and use both vision and olfaction to find prey. The lineages that are characterized by active foraging species have much more developed chemosensory abilities. Teiids (whiptails) have long protrusible tongues that they use to sample chemical cues in the environment by tongue-flicking much like snakes. Conversely, iguanians (mostly visually hunting lizards) do not have as well-developed olfactory systems, and rely less on chemical cues to find prey.

In biology there are exceptions to every generality, and the foraging dichotomy in lizards is no different. In reality, there probably is a rough gradient in foraging modes among various genera and families. Individuals also alter their foraging behavior depending on circumstances, such as when prey is extremely abundant or patchy. Horned lizards are examples of lizards that do not neatly fit the foraging dichotomy. Horned lizards have a tank-like body form that seems to go along with their dietary specialization on ants. An individual's home range includes several harvester ant mounds that it visits to obtain its meals. Despite the exceptions, considering the two extremes of foraging mode is a convenient way to gain insight into the diversification of lizards.

(B) FINDING PREY - SNAKES



The features that define snakes are intimately entwined with their modes of foraging and locomotion. Of course, the most salient feature of a snake is being long and thin. The elongate shape of snakes, coupled with lack of limbs, presents certain obstacles as well as opportunities for foraging. Limblessness keeps snakes very much in contact with the substrate, whether on the ground or in trees, and snakes are especially good at obtaining chemical cues from the substrate. They possess very well developed chemosensory abilities, and use their forked tongues and Jacobsen's organ to constantly sample their surroundings. Chemical cues orient snakes to the trails used by prey, as well as trails of potential mates or competitors.

One constraint of snake body form is that a small head goes along with a thin body. How have the problems of having a small head and not having limbs to manipulate prey been reconciled in snakes? The answer is snakes have evolved specializations to eat very large prey, and to eat infrequently. It is well known that snakes engulf large prey whole. Other limbless reptiles do not generally engulf their prey as snakes do. Limbless lizards such as the slender glass lizard eat much smaller prey. Snakes have very specialized heads to deal with eating large prey. They have very loosely constructed skulls that permit flexibility and movement. Skull elements are reduced, although the floor of the braincase is strong. The two sides of the lower jaw are not fused together in front The upper jaw is not attached to the skull and also not fused in the front, so snake jaws are comprised of four elements that can be moved independently.

Snakes typically engulf their prey by taking advantage of the loose configuration of upper and lower jaws and "walking" their heads around the prey with side-to-side movements. Sharp backwardly curved teeth hold one side of the jaw in place while the other side is moved forward.These adaptations allow both large and small species of snakes to eat

amazingly large prey for their body size. It is not uncommon for pit vipers to eat prey heavier than they are, and larger in diameter than their own heads. Vipers are especially good at eating large prey quickly.

(C) Killing Prey - snakes

All snakes are carnivores and subdue their prey in three basic ways that more or less correspond to evolutionary lineages of snakes. Subduing prey by constriction is used by several genera of snakes in Kansas, including rat snakes, king snakes, and their allies. Constrictors immobilize and often suffocate their prey by constricting it before they begin to swallow it. Other snakes, including garter snakes and water snakes, simply subdue their prey by swallowing it alive. The third method of subduing prey is the use of venom by pit vipers. Taking large prey can be dangerous, and numerous scars on large snakes attest to confrontations they have had with prey. Pit vipers usually strike and release, then track the prey after it is incapacitated. The venom of pit vipers begins to breaks down tissues inside the prey, allowing them to digest large prey more easily.

(D) Locomotion in Snakes

Limblessness has certain advantages for locomotion. A long, thin body enables snakes to negotiate narrow openings and move through difficult terrain, where limbs may hinder more than help. All snakes have at least 120 vertebrae in front of the tail, some as many as 400. Each vertebra has projections that strengthen connections between them, and complex muscular arrangements connect overlapping sets of vertebrae. Snakes have the same number of ventral scales as vertebrae, and the ribs from each vertebra are connected to the ventral scales. This system allows snakes to precisely control movements along their entire body.

Snakes can move in several ways, including the familiar lateral undulation. Snakes moving this way generate force against objects in the environment, and move forward in a wave-like motion from point to point. Some—for example coach whips and racers can move surprisingly fast with lateral undulation. Lateral undulation is well suited for negotiating complex habitats such as tall grass, debris piles, and rock piles. The ability of snakes to negotiate these habitats with ease undoubtedly inspired the quip, "like a snake in the grass."

Snakes also move with rectilinear locomotion, reminiscent of a caterpillar crawl, with the snake's body stretched out. Snakes moving by rectilinear locomotion push their ventral scales onto the ground in several places, pull themselves forward and anchor their ventral scales in a forward position. It is not uncommon to find large rattlesnakes traveling by rectilinear locomotion. Once disturbed, however, they will usually switch to lateral undulation to retreat faster.

In concertina locomotion, a snake will move from point to point by pushing itself onto the ground and lifting and pulling its body forward.

Sidewinding is an efficient mode of locomotion used by some snakes that live in soft, sandy habitats. There are no sidewinders in Kansas, but sidewinding arose independently in several species of vipers that live in deserts around the world.

3. Reproductive Modes in Squamates

The herpetological naturalist quickly learns that some snakes like pit vipers, water snakes, and garter snakes give birth to their young alive (viviparity), whereas many others lay eggs (oviparity). Inside shelled eggs that are laid, embryos of viviparous squamates are nourished from yolk. The calcareous shell is not added to the eggs of viviparous species, but babies are born in a sac of extraembryonic membranes they promptly rupture. In general, mothers provide little or no nourishment to retained eggs, but females of a few species of viviparous skinks in the Neotropics are known to provide nourishment to embryos via a placenta-like structure.

There are pros and cons to viviparity and oviparity. Once eggs are laid, oviparous females are no longer burdened with carrying a clutch of eggs. Eggs can be laid in places favorable to hatchling survival and growth, even if such places are outside the usual habitat of females. Viviparous females, on the other hand, avoid problems that can befall eggs, such as nest predation, disease, and poor conditions for incubation (e.g., too cold, hot, or dry). Live bearing snakes and lizards can use behavioral thermoregulation to control their body temperatures, and hence the incubation temperature of eggs retained inside their bodies. Therefore it makes sense that viviparity is common in cold climates, whether at high latitudes or high elevations. Some skinks and other lizards protect their nests, and retention of eggs inside the female's body can be thought of as an extension of parental care of eggs. Costs of viviparity include poor performance of gravid females, and consequent increased risks of predation.

Many families, genera, and species of squamates have independently evolved live bearing from their egg-laying ancestors. Viviparity evolved at least 45 times in lizards, and more than 30 times in snakes. In reality, there is an oviparity-viviparity continuum in squamates that ranges from eggs laid with embryos only beginning to develop, to fully developed babies born alive. In most oviparous lizards, about half of embryonic development occurs before the eggs are laid.

4. Parthenogenesis

Some species of lizards and snakes reproduce asexually. There are no males or sperm, and mothers produce identical daughters—clones. This type of reproduction is called parthenogenesis and is known worldwide in seven lineages of lizards and one snake lineage. Lizards that reproduce parthenogenetically, appear to have arisen when two different sexual species hybridized. It is known, for example that *C. uniparens* originated from hybridization events between *C. gularis* and *C. inornatus*.

Recent research has also discovered that many lizard and snake females can produce offspring parthenogenicly or sexually. In Kansas these include the copperhead and possibly other pit vipers, garter snakes and water snakes.

F. Conservation of Kansas Herpetofauna

1. Causes of Concern

Amphibians and reptiles have been affected by the same factors that have resulted in decline of other kinds of organisms: habitat alteration, harmful invasive species, environmental contamination, and commercial exploitation. Although there are no species we know of that have been extirpated from the state, there are unfortunate examples of how each of these factors has affected Kansas' herpetofauna. The good news is that herps have been granted the legal status of other wildlife, and are more appreciated than ever by the public.

Currently in Kansas, the state lists nine species of amphibians and seven species of reptiles on the Threatened and Endangered (T & E) species list. There are also two species of amphibians and 6 species of reptiles listed on the Species in Need of Conservation (SINC) list.

2. Habitat

Amphibians and reptiles as a group tend to persist, but the ever increasing number of roads, increasingly fragmented habitats, and altered wetlands negatively affect local populations. Herpetological conservation is a relatively new endeavor, and there are not many detailed studies on the effects of habitat change. Forestry practices and range management affect herpetological communities mostly by altering the mosaic of forested and open habitats. Different species respond in their own way to these kinds of changes, and detailed studies of the effects of land use practices are becoming more common.

3. Environmental Contamination

Contamination from pesticides, runoff, and other kinds of pollution are known to affect herps. Several scientific studies show that various species of herps accumulate contaminants, but the population-level effects are not easy to document. There is one excellent case study, however, that should serve as a warning for the future. In the 1970s evidence was uncovered that was resoundingly similar to the DDT pesticide crisis that caused eggshell thinning in birds. Robert Fleet found high levels of pesticides in a snake community in southern Texas. The snake species that reproduce by laying eggs were all but absent from the community, whereas live-bearers remained. Current research is investigating even more insidious effects of contaminants on herps, such as disruption of the endocrine system that can lead to reproductive failure, malformed limbs, and other problems.

4. Commercial Exploitation

More people than ever before appreciate herps, and their appreciation motivates many people to keep herps as pets. It is not uncommon for boys and girls, or even adults, to catch a frog, lizard, snake, or turtle and want to keep it. Except for endangered species, this type of use is probably not a problem for conservation of herps. Wildlife laws in Kansas are not designed to control individual people's experiences with small numbers of amphibians and reptiles, but rather to monitor the commercial use of wild herps that could be unsustainable. However, you should consult the Kansas Department of Wildlife Parks & Tourism and local animal control officers for details.

Kansas state law prohibits the use of any wild-caught amphibian or reptile or any of their parts, eggs, or offspring for commercial purposes. For personal enjoyment, a person may collect non-listed Kansas species, but none may be sold or traded. They may be captured by any device that is not designed to cause death or serious injury. If released, individuals must be returned to the place where they were captured. Check with the Kansas Department of Wildlife, Parks & Tourism Office of Law Enforcement, for details on capturelimits and season.

5. IDENTIFYING AMPHIBIANS & REPTILES

There is a large amount of information available to help students of amphibian and reptile natural history in Kansas. Several field guides, checklists, and Websites (like the Kansas Herp Atlas - http://webcat.fhsu.edu/ksfauna/herps/index.asp) include accurate and sometimes extensive natural history information, keys to identification, drawings, and photographs.

Naturalists are already familiar with use of dichotomous keys, field guides, or photographs to aid in identifying herps.

6. HUNTING FOR HERPS

The most common way to find herps is simply to search for them in their habitat. Naturalists should take the following equipment: several plastic bags for amphibians, cloth bags for reptiles, a pry tool for turning over rocks, perhaps a potato fork for raking through leaf matter. Additionally, it would be wise to wear long pants, boots, and a long sleeved shirt.

While searching for herps on foot, keep an eye out for active lizards and snakes, and look under suitable cover where herps may be hiding. Many species take refuge under rocks, underneath and inside fallen logs, and under the bark of standing snags. The hook or rake is useful for turning rocks and tearing apart rotten logs. Microhabitats are disturbed when searching for herps, and it is important to **put logs and rocks back in their original positions**. Piles of boards, sheet metal, junk piles, and fallen down buildings provide lots of hiding places for herps and are excellent places to search.

Never try to catch a venomous snake without a compelling reason. Naturalists usually do not have a compelling reason, and it simply isn't worth the risk of snakebite to catch and handle pit vipers on a naturalists' outing. Venomous snakes are easy to identify without capture. Pit vipers can often be photographed in situ, and if found undisturbed, will often stay put long enough for others in the group to arrive and observe them.

The number of herps found is basically a function of the time spent in the field, and the intensity of the search. The best collectors tend to stay out the longest, be very active, walk long distances, and have a good feel for what kinds of microhabitats are likely to be productive. In the Peterson Field Guide, Amphibians and Reptiles of Eastern/Central North America, Conant and Collins (1991) give a classic overview of herp catching and handling techniques, illustrations of how to hold live herps, and the common tools used by herp-oriented naturalists. It takes a lot of practice to catch herps by hand, and there is no formu1a for instant success. Most herps are caught by hand grabbing, though be advised the reptiles may bite. Some nonvenomous snakes and lizards will bite hard and can draw blood. Learn to be quick.

7. Coverboards & PVC Pipe Traps

Coverboards and PVC pipe traps function by creating an artificial cover that is attractive to herps. Coverboards are simply sheets of plywood or other material that are laid out in suitable habitat. Lengths of PVC pipe driven into the ground in wetlands retain water, and provide a good refuge for frogs, especially tree frogs. These traps work well in many situations, and have the great advantage that herps do not remain trapped. They do not have to be checked daily, and maintenance is very low compared to pitfall traps. Coverboards and pipe traps can be configured in grids for standardized sampling.

A Checklist to Native Amphibians, Reptiles, and Turtles in Kansas

Amphibians - Class Amphibia

Salamanders - Order Caudata

Family Ambystomatidae - Mole Salamanders
Barred Tiger Salamander *(Ambystoma mavortium)*
Smallmouth Salamander *(Ambystoma texanum)*
Eastern Tiger Salamander *(Ambystoma tigrinum)*

Family Plethodontidae - Lungless Salamanders
Longtail Salamander *(Eurycea longicauda)* - Threatened
Cave Salamander *(Eurycea lucifuga)* - Endangered
Grotto Salamander *(Eurycea spelaea)* - Endangered

Family Proteidae - Mudpuppies
Red River Mudpuppy *(Necturus louisianensis)*
Common Mudpuppy *(Necturus maculosus)*

Family Salamandridae - Newts
Eastern Newt *(Notophthalmus viridescens)* - Threatened

Frogs & Toads - Order Anura

Family Bufonidae - True Toads
American Toad *(Anaxyrus americanus)*
Great Plains Toad *(Anaxyrus cognatus)*
Green Toad *(Anaxyrus debilis)* - Threatened
Fowler's Toad *(Anaxyrus fowleri)*
Red-spotted Toad *(Anaxyrus punctatus)* - SINC
Woodhouse's Toad *(Anaxyrus woodhousii)*

Family Hylidae - Treefrogs & Allies
Blanchard's Cricket Frog (*Acris blanchardi*)
Cope's Gray Treefrog (*Hyla chrysoscelis*)
Eastern Gray Treefrog (*Hyla versicolor*)
Spotted Chorus Frog (*Pseudacris clarkii*)
Spring Peeper (*Pseudacris crucifer*) - Threatened
Boreal Chorus Frog (*Pseudacris maculata*)
Strecker's Chorus Frog (*Pseudacris streckeri*) - Threatened

Family Microhylidae - Narrowmouth Toads
Eastern Narrowmouth Toad (*Gastrophryne carolinensis*) - Threatened
Great Plains Narrowmouth Toad (*Gastrophryne olivacea*)

Family Ranidae - True Frogs
Crawfish Frog (*Lithobates areolatus*) - SINC
Plains Leopard Frog (*Lithobates blairi*)
Bullfrog (*Lithobates catesbeianus*)
Bronze Frog (*Lithobates clamitans*) - Threatened

Southern Leopard Frog *(Lithobates sphenocephalus)*

Family Scaphiopodidae - North American Spadefoots
Plains Spadefoot *(Spea bombifrons)*

Reptiles - Class Reptilia
Lizards & Snakes - Order Squamata

Family Anguidae - Glass Lizards
Western Slender Glass Lizard *(Ophisaurus attenuatus)*

Family Crotaphytidae - Collared & Leopard Lizards
Eastern Collared Lizard *(Crotaphytus collaris)*

Family Gekkonidae - Geckoes
Mediterranean Gecko *(Hemidactylus turcicus)* – Introduced

Family Lacertidae
Western Green Lacerta (*Lacerta bilineata*) – Introduced
Italian Wall Lizard (*Podarcis siculus*) – Introduced

Family Phrynosomatidae - Spiny Lizards
Lesser Earless Lizard *(Holbrookia maculata)*
Texas Horned Lizard *(Phrynosoma cornutum)*
Prairie Lizard *(Sceloporus consobrinus)*

Family Scincidae - Skinks
Coal Skink *(Plestiodon anthracinus)*
Five-lined Skink (*Plestiodon fasciatus*)
Broadhead Skink (*Plestiodon laticeps*) - Threatened
Great Plains Skink (*Plestiodon obsoletus*)
Southern Prairie Skink (*Plestiodon obtusirostris*)
Northern Prairie Skink (*Plestiodon septentrionalis*)
Ground Skink *(Scincella lateralis)*

Family Teiidae - Racerunners and Whiptails
Six-lined Racerunner *(Aspidoscelis sexlineata)*
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Family Leptotyphlopidae - Slender Blind Snakes
New Mexico Blind Snake *(Rena dissecta)* - Threatened

Family Colubridae - Harmless Egg-laying Snakes
Eastern Glossy Snake *(Arizona elegans)* - SINC
Eastern Racer *(Coluber constrictor)*
Prairie King Snake (*Lampropeltis calligaster*)
Speckled King Snake (*Lampropeltis holbrooki*)
Milk Snake (*Lampropeltis triangulum*)
Coachwhip (*Masticophis flagellum*)
Rough Green Snake (*Opheodrys aestivus*)
Smooth Green Snake (*Opheodrys vernalis*)
Great Plains Rat Snake *(Pantherophis emoryi)*
Gopher Snake (*Pituophis catenifer*)
Longnose Snake (*Rhinocheilus lecontei*) - Threatened
Western Rat Snake *(Scotophis obsoletus)*
Ground Snake *(Sonora semiannulata)*
Flathead Snake *(Tantilla gracilis)*
Plains Blackhead Snake *(Tantilla nigriceps)*

Family Dipsadidae - Rear-fanged Snakes
Western Worm Snake (*Carphophis vermis*)
Ringneck Snake (*Diadophis punctatus*)
Western Hognose Snake (*Heterodon nasicus*) - SINC
Eastern Hognose Snake (*Heterodon platirhinos*) - SINC
Chihuahuan Night Snake (*Hypsiglena jani*) - SINC

Family Natricidae - Harmless Live-bearing Snakes
Plainbelly Water Snake (*Nerodia erythrogaster*)
Diamondback Water Snake (*Nerodia rhombifer*)
Northern Water Snake (*Nerodia sipedon*)
Graham's Crayfish Snake *(Regina grahamii)*
Brown Snake (*Storeria dekayi*)
Redbelly Snake (*Storeria occipitomaculata*) - Threatened
Checkered Garter Snake (*Thamnophis marcianus*) - Threatened
Western Ribbon Snake (*Thamnophis proximus*)
Plains Garter Snake (*Thamnophis radix*)
Common Garter Snake (*Thamnophis sirtalis*)
Lined Snake (*Tropidoclonion lineatum*)
Rough Earth Snake *(Virginia striatula)* - SINC
Smooth Earth Snake *(Virginia valeriae)*

Family Crotalidae - Pitvipers
Copperhead *(Agkistrodon contortrix)*
Cottonmouth *(Agkistrodon piscivorus)*
Timber Rattlesnake *(Crotalus horridus)* - SINC
Prairie Rattlesnake *(Crotalus viridis)*
Massasauga *(Sistrurus catenatus)*

Turtles - Class Chelonia
Straightneck Turtles - Order Cryptodira

Family Chelydridae - Snapping Turtles
Common Snapping Turtle (*Chelydra serpentina*)
Alligator Snapping Turtle (*Macrochelys temminckii*) - SINC

Family Emydidae - Box & Water Turtles
Northern Painted Turtle (*Chrysemys picta*)
Common Map Turtle (*Graptemys geographica*) - Threatened
False Map Turtle complex (*Graptemys pseudogeographica*)
Eastern River Cooter (*Pseudemys concinna*)
Eastern Box Turtle (*Terrapene carolina*)
Ornate Box Turtle (*Terrapene ornata*)
Slider (*Trachemys scripta*)

Family Kinosternidae - Mud & Musk Turtles
Yellow Mud Turtle (*Kinosternon flavescens*)
Common Musk Turtle (*Sternotherus odoratus*)

Family Trionychidae - Softshells
Smooth Softshell *(Apalone mutica)*
Spiny Softshell *(Apalone spinifera)*

SELECTED ONLINE REFERENCES

Chicago Herpetological Society http://www.chicagoherp.org/

Illinois Natural History Survey Amphibian and Reptile Collection
http://www.inhs.uiuc.edu/cbd/collections/amprep/amprepintro.html

Tree of Life: Terrestrial Vertebrates. The Tree of Life is a project containing information about the diversity of organisms on Earth, their history, and characteristics. The information is linked together in the form of the evolutionary tree that connects all organisms to each other. Website: http://tolweb.org/tree/phylogeny.html