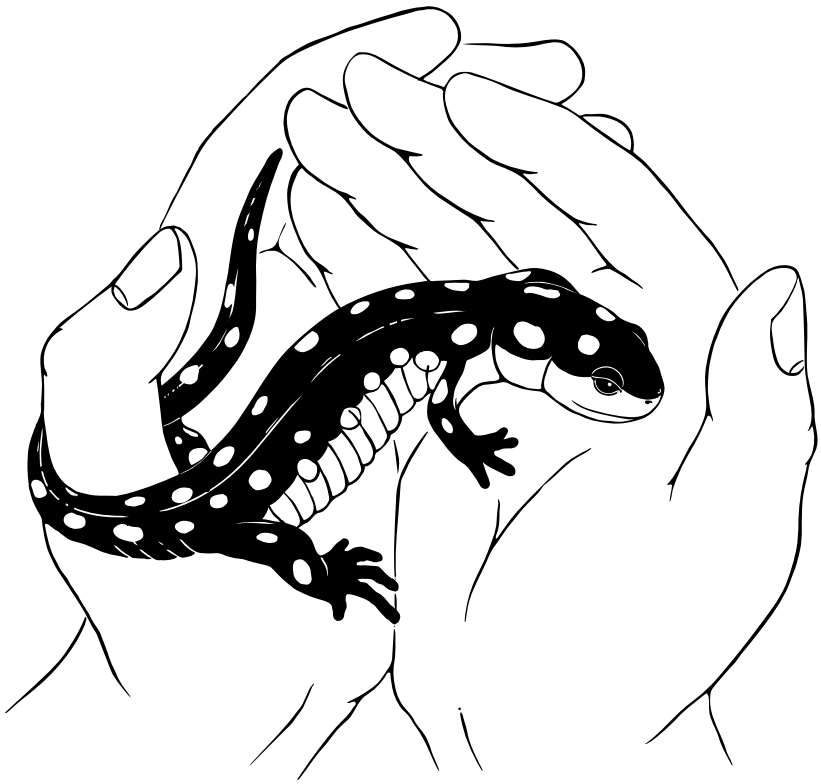
Hands-On Herpetology

Exploring Ecology and Conservation

Rebecca L. Schneider Marianne E. Krasny Stephen J. Morreale



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On the Cover: Design and illustrations of green treefrog, eastern box turtle, and eastern newt by Linda Olliver.

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About the Authors

Rebecca L. Schneider, Ph.D., is an ecologist studying wetland and aquatic ecosystems. In her research, she examines the interactions between plant communities and flowing water, both aboveground and belowground. Primary topics in her research include seed dispersal, hydrologic transport of nutrients, filtration of contaminants by plants, and streamside buffering. As an assistant professor in the Department of Natural Resources at Cornell University, Rebecca teaches about sustainable management of water resources and, through her outreach programs, provides guidance to local communities and state and national government agencies.

Marianne E. Krasny, Ph.D., is an associate professor, department extension leader, and director of graduate studies in the Department of Natural Resources at Cornell University. Through her work with the Cornell Environmental Inquiry Program, Marianne develops and evaluates university outreach programs designed to engage students and teachers in authentic environmental sciences research.

Stephen J. Morreale, Ph.D., is a zoologist whose research is focused in the field of herpetology. He has worked for many years studying turtle ecology and is a world-renowned expert on seaturtles. As a senior research associate in the Department of Natural Resources at Cornell University and the associate director of research at Cornell's Arnot Teaching and Research Forest, he devotes considerable time to interacting with students, conducting research, and teaching conservation ecology. Stephen also is active in the conservation community, working with several national agencies and international organizations.

Preface

Why an Activity Guide Focused on Herps?

"Herps" are all around us. They include amphibians, such as frogs, toads, and salamanders, and reptiles, such as snakes, lizards, and turtles. Yet surprisingly, herps have been largely ignored as a tool for educating youth about biology, ecology, and conservation. Thus, this educator's guide addresses a strong need for educational resources focused on the science and conservation of amphibians and reptiles.

Because *herps are plentiful, diverse, and nearby*, they offer many possibilities for teaching science and conservation to young people. Unlike birds or mammals, most frogs, salamanders, and turtles are relatively docile and easy to hold. When treated properly, they do not show fear or threatening postures, which can be a distraction to students and an obstacle to learning. Also, amphibians generally are harmless, and in much of the northern United States and eastern Canada there are few poisonous species of reptiles, so many fears and concerns can be set aside.

Young people and adults studying herps will find fascinating differences among the various groups in their basic physiology, morphology, behavior, and adaptations to their environments. Thus, *herps are excellent organisms to demonstrate concepts about biology and ecology*, ranging from camouflage and thermoregulation, to food webs and competition.

Perhaps the most important reason for developing an educator's guide focusing on herps is the *urgent need for expanding conservation efforts* directed at these organisms. Because herps usually are hidden from sight, we often are not aware of their amazing abundance and importance to the overall environment. However, herps are an integral part of many ecosystems, and serve essential roles as predators on small animals as well as food for larger ones. At the same time, herp populations worldwide are suffering severe declines, and many species have become extinct in recent years. Additionally, some populations of herps in North America have experienced alarmingly high rates of malformations in legs, tails, eyes, and internal organs. Scientists and the public are still searching for explanations for these mysterious declines and malformations—with the objective of preserving the diversity and richness of amphibians and reptiles.

We hope that you and the young people with whom you work will enjoy learning about the fascinating world of frogs, toads, salamanders, snakes, and turtles. At the same time, we hope you will join us in efforts to conserve these amazing and important creatures.

Acknowledgments

We appreciate the contributions of Martin Schlaepfer to this project, including the species accounts. We thank Margaret Corbit for assistance during the development phase. We also are grateful for the enthusiastic critiques provided by educators who pilot-tested many of the activities in this guide, including Andy Turner, Sanford Smith, Bonnie Peck, Keith Koupel, Carolyn Klass, Susan and Paul Grimes, Kent Gaerthe, Kimberly Fleming, and Gwen Curtis. Many others provided insights, suggestions, and support that have improved the book immensely, including Kraig Adler, Al Breisch, Nancy Bowers, Howard Evans, Harry Greene, Gretchen Finley, John Maerz, Karen Poiani, Mike Richmond, and Kelly Zamudio. Funding to initiate this project was provided as a grant from the U.S. Fish and Wildlife Service.

The book's reviewers were Lisa Robinson, a biology teacher at Oxford High School, Oxford, Alabama, and Juli Werth, a teacher of sixth-grade integrated science at Riverview Middle School, Huntington, Indiana. Kenneth Roy, K-12 director of science and safety for the Glastonbury, Connecticut, Public Schools and chairperson of the NSTA Science Safety Advisory Board, reviewed the section on safety.

All the illustrations are by Tami Tolpa, San Francisco, California, except those noted below.

The NSTA project editor for the book was Judy Cusick. Linda Olliver designed the book and the cover, did book layout, and drew the illustrations on pages 18, 19, 45, 46, and 53. Catherine Lorrain-Hale coordinated production and printing.

Introduction

How to Use *Hands-On Herpetology*

The goal of *Hands-On Herpetology* is to provide an introduction to the study of reptiles and amphibians and to present opportunities for young people ages 10–18 (grades 5–12) to become involved in their conservation. This book is designed as an instructional guide for many educators, including upper-elementary, middle, and high school teachers, 4-H and summer youth camp instructors, and nature center educators. The material provides a thorough introduction for newcomers to the world of amphibians and reptiles, and also presents relevant and challenging activities for more experienced herpetologists.

The information and activities have been divided into five sections. In Section I, we explain the basics of interacting with herps, including handling, safety, permits, and regulations. We also provide an introduction to herp biology. This section provides a critical underpinning for the remainder of the book. The next three sections include background information and hands-on activities to illustrate basic principles that are common to many species and their communities: We focus on the biology of reptiles and amphibians (Section II), their ecology (Section III), and their conservation (Section IV).

In Section V, students examine two critical conservation issues currently affecting amphibians—malformation and declining populations. In doing so, they become familiar with many issues scientists face when researching environmental phenomena. For example, students learn about different research approaches, ranging from monitoring to controlled experiments, and about how policymakers use research findings. They also learn how careful observations conducted by young people and volunteers, as well as by professional scientists, can contribute to solving disturbing environmental problems. In addition, they learn about opportunities to use the Internet to link up with groups of students, volunteers, and scientists who are monitoring herp populations and sharing their data. Finally students see how the knowledge and skills they learned through the activities in previous sections can be applied to solve the double mysteries of herp decline and amphibian malformations.

There is considerable variety among the 29 activities presented. Although most of the activities can be conducted anywhere in North America, we draw mainly on examples of animals from the northeastern states. About half of the activities take place indoors, and the other half outdoors. For the outdoor activities, some are best conducted in early spring whereas others work well throughout the warmer months when herps are active. The activities also vary in their degree of difficulty; some are most suitable for upper-elementary and middle school students, whereas others may be appropriate for high

school students. You will need to consider which activities are most appropriate given your students' abilities, the resources available, and season of the year.

Hands-On Herpetology is not intended to be a comprehensive, sole source reference. Instead we strongly recommend that educators complement its use with field guides identifying amphibians and reptiles in their own regions. As an appendix, we have included example species accounts (pages 133–145) for three amphibians (the spotted salamander, the American toad, and the eastern newt) and one reptile (the snapping turtle). Such accounts can help you identify herp species and familiarize you with their natural history and conservation status. You may want to contact your state natural resources agency or a local university for more accounts of species that occur in your region.

The *National Science Education Standards*

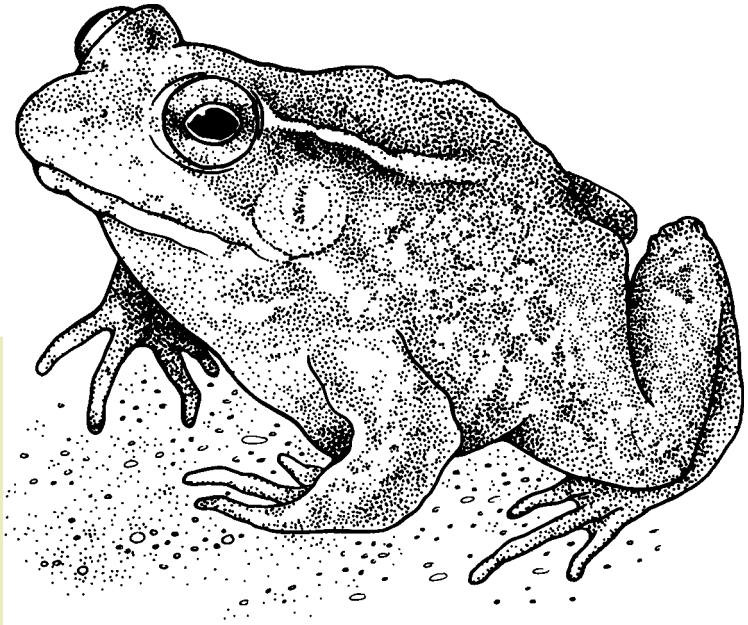
In 1996 the National Research Council of the National Academy of Sciences published the *National Science Education Standards*, a set of guidelines for the teaching of science in grades K–12. These standards move science teaching away from vocabulary lists and "canned" laboratories with pre-set outcomes toward the teaching of science as an active process that requires not only knowledge but also reasoning and thinking skills.

The activities in this book are designed to embrace the philosophy set forward by the creators of the National Standards. As students carry out the activities, they will take an active approach to learning through hands-on activities, group discussions, and participation in Internet-facilitated research activities. In general, Section II of the guide focuses on Life Science standards; Section III focuses on Life Science and Science as Inquiry; Section IV focuses on Science in Personal and Social Perspectives; and Section V focuses on Science as Inquiry, Science in Personal and Social Perspectives, and the History and Nature of Science. The *National Science Education Standards* for grades 5–8 and grades 9–12 covered in each chapter are indicated at the beginning of the chapter. In addition, two Standards matrixes follow—"Correlations with the *National Science Education Standards* for Grades 5–8" and "Correlations with the *National Science Education Standards* for Grades 9–12."

Section I

Getting Started

Before starting any of the activities in this guide, we strongly recommend that you read the information in this section. Here we cover the critically important issues of how to handle amphibians and reptiles, and safety issues concerning these animals and field activities in general. We also discuss permits and regulations relating to the collecting, handling, and raising of herps. At the end of this section, you will find an introduction to the biology of amphibians and reptiles—"Basic Facts about Herps"—which provides important background for understanding the subsequent chapters.



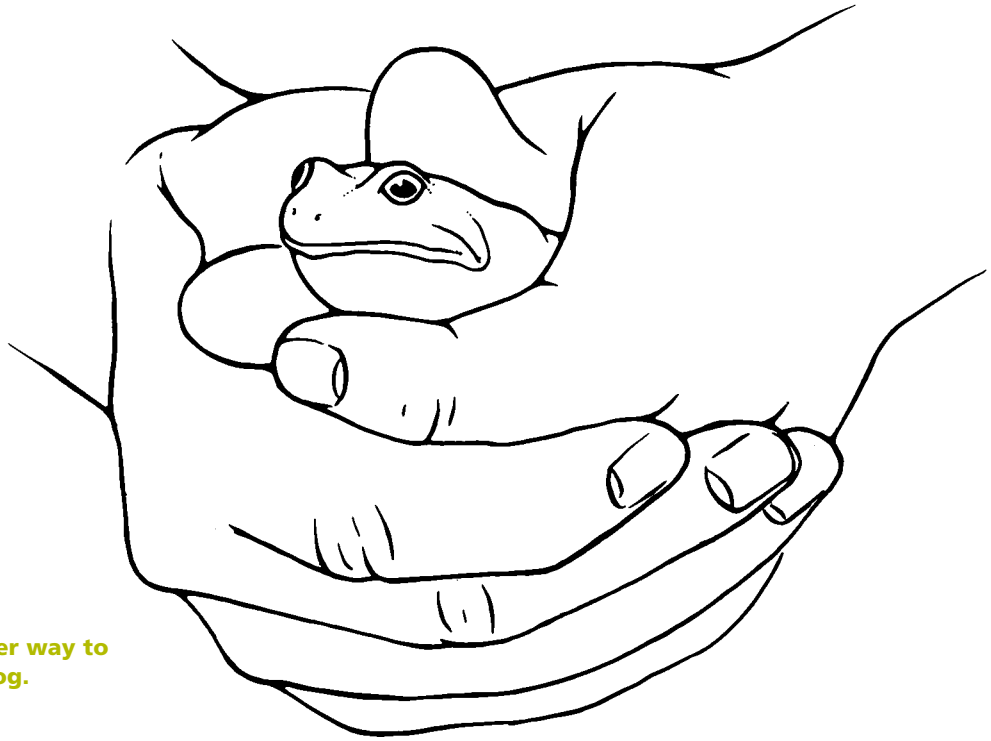
Care and Handling of Live Herps

When handling any live animal, it is important to always keep two safety issues in mind: first is the safety of the person who is searching for or holding the animal, and second is the safety and welfare of the animal itself.

People may believe naively that because herps do not show facial expressions or fear, or have obvious defensive postures, they cannot be hurt. However, herps are still very much living organisms, vulnerable to stress and pain caused by improper handling and confinement. Humans also can harm entire herp populations by destroying their homes or nests, as well as by disturbing their habitats on a broader scale. If you follow the guidelines below for safe capture, care, and handling of herps, you will go a long way toward ensuring both your safety and that of the reptiles and amphibians you are studying.

When searching for herps, *take care not to destroy their homes or injure the animals*. Lift rocks gently and lower them carefully back to their original position, so as not to crush soft-bodied salamanders and other creatures living underneath. Return logs with the original, moist side down because they already may be decomposing and may provide homes for many organisms. Don't tear up logs or tree stumps to get to salamanders, lizards, or snakes because this permanently destroys their nests and their homes.

Keep handling of herps to a minimum in order to protect the animals. Amphibians have delicate skin that needs to be kept moist. Continuous handling dries out their skin and removes the mucous-like protective covering that is present on many amphibians. Without this covering, the amphibian's skin may suffer from abrasion and infection. Even



The proper way to hold a frog.

tough-skinned reptiles can be stressed by handling and restraint. Therefore, the less they are subjected to handling, the better. A useful method for looking closely at and displaying animals to a large group is to place the animal in a clear, plastic container. With the addition of a little moisture from leaves or a wet towel, a clear container can make a very suitable viewing device.

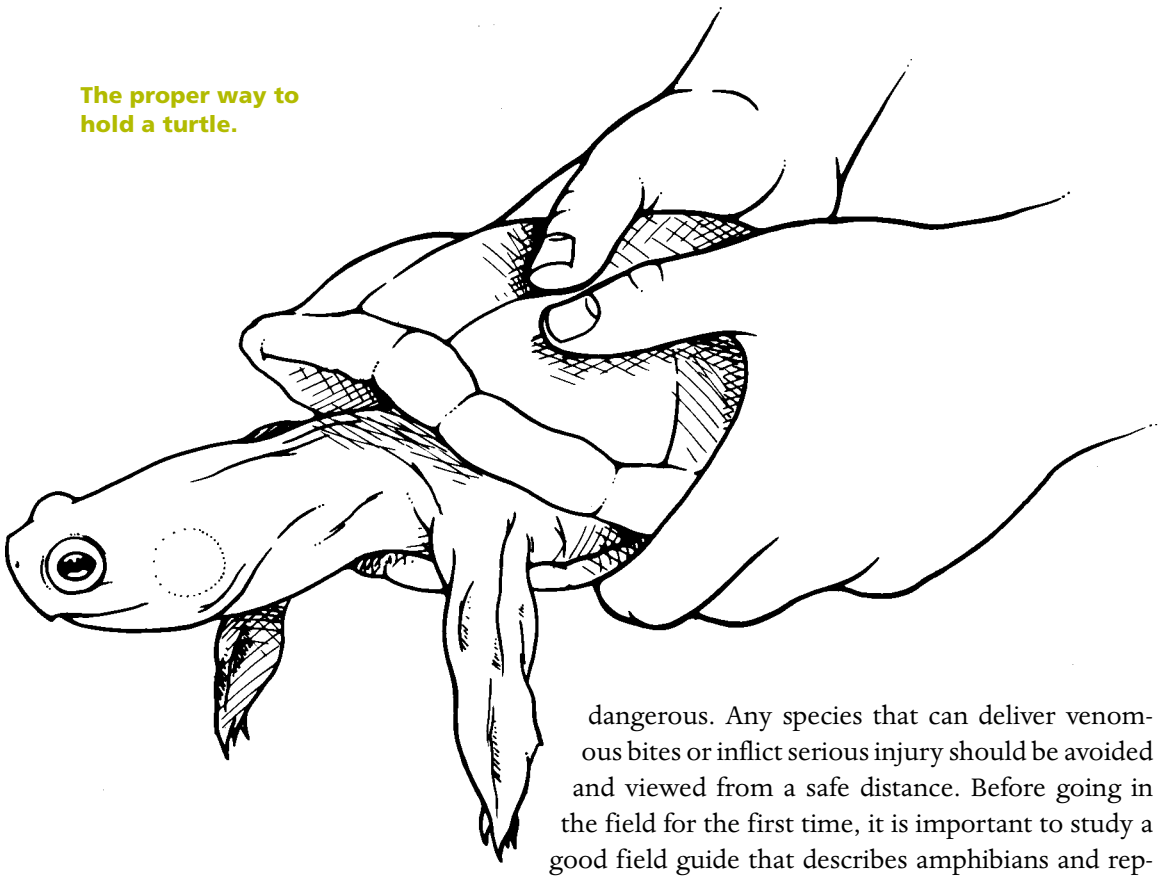
If an animal feels secure and comfortable, it is less likely to try to escape or bite. Therefore *hold all organisms gently, but firmly*. Salamanders and frogs have particularly tiny and fragile limbs, toes, and tails. You can hold them by gently cupping your hand to support their bodies. To look at them more closely, you may have to restrain their limbs and keep them from wiggling without squeezing too hard. This takes a little practice, and adults should assist children in holding the animals until the children are comfortable and competent at it. A great technique for the newcomer and experienced alike is to always crouch or sit on the ground when restraining an animal. That way, when they squirm out, there won't be any shock or damage from crashing to the ground.

Snakes need to have their bodies supported while their heads are being immobilized. Use the thumb and fingers to gently restrain the sides of their heads near the neck, but don't let the body flail about freely. It is best to just observe a snake from a bit of a distance if the species is unknown. Whether venomous or not, snakes of many species will bite to protect themselves. Also, don't pick up snakes that have obviously just eaten. This will be apparent from a swollen lump along their body, which is their recent meal bulging in the gut. When disturbed, many snakes will regurgitate their food, either as a defensive strategy or to help them escape. At the least, this can be a bother to the snake, and often is a loss of valuable energy. In general, when thinking about handling a snake or any other animal, remember to do so only if you can ensure your safety and the animal's safety.

Lizards also tend to bite when handled, which can be startling but rarely painful. Do not pick up a lizard by its tail. Many lizards and salamanders have adopted a peculiar defensive strategy in which they shed their tails when they are grabbed. Although this strategy may allow the animal to escape its predator, it can come at great expense. The energy they will need to invest into growing a new tail can take away considerably from their ability to reproduce, grow, or even survive.

A notoriously aggressive character is the snapping turtle. It is extremely ornery and should not be handled (or, at the very least, it should be handled with extreme care by someone with experience). If you must pick up a snapper, use a shovel to support the body and to keep you out of the reach of its bite. Also, do not lift it far off the ground, because it can move off the shovel easily. These are not the only turtles to beware of. In fact, all turtles can inflict a very painful bite, and many have sharp claws that will scratch you. For safety reasons, hold turtles securely by the upper shell, with one or two hands grasping the sides of the shell, while keeping fingers and hands well away from the head. Also keep the turtle's head aimed away from you so it can't latch on to a nearby part of your body. Never place your hands in front of the turtle's face or even close to its head. And remember, some turtles have very long necks and can reach around to bite.

The most useful safety tool is knowledge and familiarity with the animals in your local area. In some regions reptiles such as snakes, lizards, and alligators can be downright



The proper way to hold a turtle.

dangerous. Any species that can deliver venomous bites or inflict serious injury should be avoided and viewed from a safe distance. Before going in the field for the first time, it is important to study a good field guide that describes amphibians and reptiles in your area.

Keep all herps out of the direct sun so they will not dry out or overheat. Herps are ectotherms, or animals that derive body heat from external sources. Usually they avoid overheating in their natural environments by immersing themselves in water, burrowing in the soil, or seeking refuge under leaf litter. Therefore, when restraining amphibians and reptiles you may want to provide objects for shade and moisture, such as damp leaves or soil. Also you should try not to hold them in your hands for too long. A small animal on a cold day can raise its temperature way above normal, simply by absorbing heat from your body. The best way to avoid causing stress from heat or water loss is to restrain the animals only minimally or not at all, and try not to alter their conditions too much from those of their natural environment.

After handling herps, return them to their natural habitats as soon as possible. Excessive handling and confinement stress these animals in many ways. Also, because herps have homes and preferred territories, it is important to return each animal to the place where it was found. Many amphibians and reptiles when displaced will undergo long and difficult journeys attempting to return to their original homes. Even if the release site seems acceptable, a relocated animal does not easily find a suitable home, and often is vulnerable to predators while searching for one. When returning an animal, try to return it to the same exact spot where it was found. If it was found under a rock or a log, don't place

the object on top of the animal. Instead, replace the cover object to its original position first, then place the animal alongside, so it can easily and safely crawl underneath.

Safety Concerns

The good news about working with herps in the northern United States and eastern Canada is that only a few species are poisonous, and even those are relatively scarce. Thus the likelihood of interaction with a dangerous herp is low, and in many areas negligible. Nonetheless, as is true when handling any live animal, you should use caution and common sense. In the southern states, there is a much greater variety of dangerous reptiles and you should be especially cautious and knowledgeable before attempting to handle them.

The basic rules of herp safety are (1) do not pick up any animal unless you need to, and (2) know the animal before you pick it up. Before making a move, you should be able to identify the species and be somewhat familiar with its biology and behavior. Most important is the ability to identify poisonous snakes in both their juvenile and adult stages. Do not pick up any snake if you are uncertain whether it is poisonous! And remember that even turtles and nonpoisonous snakes may deliver a painful bite if frightened or mishandled.

Out in the field, use the following commonsense guidelines to avoid an unwanted interaction with a snake or other herp. When looking under objects, always lift them with the exposed side pointing away from you. That way, if a snake is present, it will not be facing you directly. Always check the surface of rocks or logs before leaning or sitting down on them. If you are walking through terrain likely to have venomous snakes, walk slowly and look at the ground while you are walking. Scan ahead and around you for any snakes within a radius of approximately 2-3 m (7-10 ft). Don't worry about snakes at greater distances because this distance gives you plenty of time to react. Stop and look around for snakes and listen before becoming engaged in a conversation or in observing plants, rocks, or other animals.

Although avoiding poisonous snakes is the best defense, be prepared in case of a snakebite. First, in advance of your field trip, locate a hospital equipped to deal with snakebites. Discuss with a trained medical technician the best method of action to take if someone in your group is bitten. Also, come up with a plan beforehand for transporting someone to a nearby treatment center. People who are well informed and have a prearranged plan always make the best responses to snakebites.

Next, expect the victim of a snakebite to experience pain. Being bitten by a snake can hurt a lot, even when no venom is injected—imagine the pain of a sharp nail driven into your hand, arm, or leg. In any circumstance, do not panic. If the snake was poisonous, the victim should have half an hour or longer before there are serious effects. Keep the victim quiet and calm, if possible. Try to have the victim exert minimal effort while you are getting him or her to a vehicle and then to a nearby treatment facility. It is very important not to overreact or to waste time in often fruitless, and sometimes dangerous, self-administered treatment. Get to a treatment center and let a professional take it from there. If there is no suitable treatment center in your area, it is essential to learn much more about venomous snakes and forms of treatment in advance.

Bites from snakes and turtles are not the only potential sources of concern. Some toads, frogs, and salamanders exude poisonous fluids from glands in their skin. These secretions generally do not affect human skin, but the moist membranes of your eyes, mouth, and nose are extremely sensitive. Therefore, do not wipe your eyes, nose, or mouth after handling toads and other herps. In addition, always wash your hands before eating or drinking. Antibacterial soap or wipes can come in handy for this purpose.

Be prepared for other dangerous and annoying creatures in the field. Bee stings and spider bites are a more likely threat than snakebites. If someone in your group is allergic to bites and stings, be sure to carry appropriate medication. You can use bug spray where mosquitoes, flies, or ticks are common. You don't need to place it directly on your skin but instead can spray it on a hat or neck scarf and wear a long-sleeved shirt. Lyme disease, a serious bacterial infection transmitted by deer ticks, is a growing problem throughout some parts of the United States. If you are working in an area known to have deer ticks, keep as much skin covered as possible. Wear long-sleeved shirts and tuck your pant legs into long socks. Upon returning from the field, check yourself thoroughly for the tiny ticks before they have a chance to bite. Remove your field clothes before entering a living area and place them into a bag or directly into the laundry. Drying clothes at a high heat setting for 20 minutes will kill the ticks.

Also be aware of toxic plants when hiking in the outdoors. Poison ivy is well known, but stinging nettles and other plants may be present as well. You may want to invest in a good plant guide and learn the characteristics of the potential problem plants in your area.

Prior to working with herps, you should become familiar with your local school system's safety regulations, standards, and policies. Boards of education often have written policies relative to use of animals in the classroom and out in the field. Individual school practices may also address your responsibilities for the safety of students during laboratory or field experiences. The school nurse should be contacted prior to field experiences to determine requirements for being aware of students with allergies or other medical concerns and for administering medications. If you are a middle or high school science teacher, you should review your science department's Laboratory Safety Standard Plan (Chemical Hygiene Plan required by OSHA in most states) as an additional safety resource.

When preparing for the field, take sensible precautions, including wearing a hat and using sunscreen to avoid sunburn, carrying a water bottle, and wearing socks and solid shoes that cover your feet. Also let someone know where you are going ahead of time, and when you plan to return. Many field activities take place along the edges of ponds and streams; thus, good water safety practices should be followed. Expect to get wet and dress appropriately. Young children should always be supervised by an adult, and in some areas, it may be appropriate for youths to wear life jackets.

By taking a few precautions beforehand and exercising care during your excursion, you and your youth group can have great fun in the field—and learn a lot, too!

Permits and Regulations

Many states require permits for collecting vertebrates. Contact your state natural resources or environmental conservation agency to determine what regulations apply to the activities you are planning. If a permit is needed, the application process may take several weeks to months, depending on the status of the species in which you are interested.

Some animals are highly protected, either at the state or federal level. At the least, these animals usually require special permits that only allow very specific activities. If an animal is listed as threatened or endangered, generally no disturbance of any kind is permitted. If there is any question whether an animal is a protected species, it is best to leave it alone in its natural state.

If you are buying species from a pet store or dealer, you should ask the owner or dealer whether the species is protected. Some of the animals may have been obtained illegally, so it is important to inquire how the animals were obtained. This may be the case for native as well as exotic species. Finally, do not return purchased animals to the wild when you are finished studying them. Instead, they should be kept as pets or donated to a nature center or school. Serious problems can occur when animals are artificially introduced into natural populations where they can become sources of disturbance and disease.

Basic Facts about Herps

The study of amphibians and reptiles is called herpetology. The term is derived from the Greek word *herpeton*, meaning "creeping thing." Herpetology is unlike the study of mammals (mammalogy) or birds (ornithology) because it considers together two very different classes of organisms, instead of just one. The historical lumping together of these very different groups was probably influenced by the perception of them all as ground-dwelling, secretive, egg-laying, and "cold-blooded" creatures. Our current understanding, however, is that reptiles and amphibians differ radically in their structure, development, and natural history. In fact, scientists now believe that reptiles have much more in common with birds than they do with amphibians! Therefore, in many ways, the grouping of amphibians and reptiles as "herps" is somewhat artificial and outdated.

It wasn't until well after the development of a scientific system of classification that amphibians and reptiles became recognized as vastly distinct animals. Our current classification or "taxonomic" system started with Carl Linnaeus in 1735. His taxonomic scheme provided a powerful tool to identify and name species based on their biological characteristics and their relationships to each other. After more than two centuries of study and refinements to Linnaeus's system, our current classification system places amphibians and reptiles into distinct classes, reflecting their extreme diversity of lifestyles and biological traits.

For most of the 20th century, our thinking was that at higher levels of classification, all herps fall within the kingdom Animalia, the phylum Chordata, and the subphylum

Vertebrata, that is, those animals that have some sort of backbone during their development. Among the vertebrates, fish, amphibians, reptiles, birds, and mammals were considered to be major classes. Although the current classification system is pretty similar at the higher levels, scientists have made many recent changes as a result of our new understanding of relationships among vertebrates. The familiar traditional classes of fish have been further divided, and birds are now thought to be a subgroup of reptiles, often referred to as "reptiles with feathers." One thing that has remained steadfast, however, is the clear distinction between amphibians and reptiles.

Differences between Amphibians and Reptiles

At the heart of the distinction between the two herp groups is the nature of their eggs. Amphibian eggs are much more like those of the primitive vertebrates. In fact, the gelatinous eggs of amphibians represent very little change from those of their fish ancestors. A single membrane surrounds the yolk and developing embryo throughout incubation. This central egg is surrounded by a series of jelly-like capsules that help protect the embryo and buffer it from the outside world. Although the gelatinous capsules contribute greatly to keeping the egg from drying out, many amphibians can only breed in water, and those that reproduce on land must still find moist places to nest.

As a result of evolutionary changes in amphibian eggs, the reptiles became the first vertebrates to live fully on land. The reptile egg was revolutionary, in that it was the first to have a series of four membranes that compartmentalize the egg, allowing transport of nutrients, essential elements, and wastes to and from the embryo. Importantly, the reptile eggs are covered in an outer membrane, and many species further protect the eggs in a leathery shell. These outer coverings keep the eggs watertight, which has allowed reptiles to expand into all sorts of environments, including the driest deserts. If the features of a reptile egg seem familiar, that's because they are shared almost to the letter by birds and, believe it or not, mammals.

Amphibians and reptiles differ in many other ways. *Amphibian*, which comes from the Greek word *amphibios*, meaning "leading a double life," is an appropriate name for this group of animals that have moved onto land but remain very much connected to water. Evolutionary biologists describe the amphibians as transitional between fish and terrestrial reptiles. Most believe that a group of prehistoric fishes first developed legs, then with a few modifications to their lungs and hearts, became the first amphibians. They never completely broke their dependency on water, however. This shows up in two important ways. The first is in reproduction, since their eggs must remain wet or moist throughout development. The second is in their skin, which is smooth and relatively thin. Most amphibians supplement their breathing by transporting oxygen through their thin skin and into blood vessels lying just underneath. For this to be most effective, they must remain in moist or wet environments.

Reptiles, in contrast, are very well designed for life on land. Along with the self-contained and weather-resistant egg, their bodies are covered with a layer of armor in the form of scales. The scales are made of the same materials as the feathers of birds and the toenails of mammals. This outer covering protects them and prevents water loss,

which allows them to live their entire lives out of water. After reptiles first evolved from a specialized group of amphibians, they very rapidly expanded into all kinds of species and moved into all types of different habitats. For many millions of years they remained the only vertebrates in many places on land. Indeed, it wasn't until birds and mammals came along that reptiles had any real company in dry places.

Along the way, many reptiles made some pretty important improvements to their legs, which allowed them to run and better support their weight. They also were able to breathe more efficiently by expanding their chests and lungs. (Their amphibian ancestors mainly pump air into their lungs by squeezing mouthfuls of air down their throats.) Because of these and other important modifications, reptiles were able to reach larger sizes than amphibians. The biggest and most infamous group of reptiles was the dinosaurs, but even today, some lizards, turtles, snakes, and crocodile relatives are impressively large.

Scientists have pieced together the intricate relationships among amphibians and reptiles by examining fossils and by comparing living species. Fossils found in rocks over 370 million years old have shown us the fishlike appearance of one of the very early amphibians, supporting the idea that these creatures evolved from prehistoric fish. As we examine the complete fossil record, we see that over the next 100 million years or so, amphibians blossomed into a group of more than 40 families, becoming very abundant in swamps and on land. Sometime after that, however, the amphibians became greatly reduced in numbers. Currently we have identified about 4,000 species worldwide, and these belong to three major groups.

The first group, frogs, accounts for the vast majority, with over 3,500 species. There are about 100 species of frogs and toads in North America. Frogs are four-legged amphibians, well designed for hopping or jumping. They all have lungs for breathing, and many have vocal chords they use to call out loudly to attract mates. The words *frog* and *toad* are not technical terms, but are commonly applied to animals that have slightly different characteristics. In general, toads move around using small hops, while frogs tend to jump and leap.

The modern salamander group is much smaller than the frog group, with only about 390 species. The center of evolution of many salamanders appears to have been North America, which contains more than one-third of all the world's species. Salamanders are smooth-skinned, elongated amphibians that usually are very quiet and secretive. Most species are four-legged, but a few have greatly reduced limbs or no hind legs. One of the most numerous groups is the family of lungless salamanders, many species of which breathe entirely through their skin. Salamanders are widespread throughout North America, occurring in lakes, streams, swamps, and forests.

The third group of modern amphibians is a weird and mysterious group of legless, wormlike, nearly blind animals called caecilians. There are around 165 species worldwide, distributed throughout most tropical areas, including Central America. These burrowing animals look like worms, but upon close inspection it becomes apparent that they have eyes and a mouth with teeth. Since they live underground, we know little about the activities of caecilians.

The reduction in diversity of amphibians coincided with a great increase in reptiles beginning around 250 million years ago. According to the fossil record, after 50 million years of evolution, a group of amphibians underwent some changes that led to the first reptiles. It is from these primitive reptiles that many different forms evolved, including mammals, modern-day reptiles (such as lizards, crocodiles, and turtles), and a group that later branched off into dinosaurs and birds. These changes were by no means quick. During that first 50 million years or so, while amphibians were much more numerous, early reptiles slowly developed different body shapes and strategies for walking, swimming, and even flying. As their variety increased, their numbers also appeared to grow, until they became the most abundant vertebrate group on land. This was the beginning of the age of the dinosaurs, one of the most exciting times in vertebrate history. Dinosaurs were a successful and diverse group that dominated land for about 150 million years before they all became extinct rather abruptly.

These may seem like unimaginably long periods of time. But think of the crocodilians (e.g., crocodiles and alligators) and turtles, which have persisted through millions of years as the early reptiles came and went, and as the dinosaurs blossomed and then winked out of existence. They have continued to plod along, seemingly unaffected, as some of their relatives grew fur or feathers and went on to dominate the land and the skies. To us, these represent awesome events that occurred over immense spans of time. But when compared to turtles and crocodilians, which have been around a couple hundred million years, these developments appear to be no more than a series of fleeting events.

Today, the reptiles still reflect their varied and long ancestry, with over 7,000 species representing major groups that differ in some pretty radical ways. Joining the armored forms of the turtles and crocodilians are the lizards, snakes, and the lesser-known tuataras. The tuataras are the last remaining two species of a once diverse group of lizardlike reptiles. They only occur on several islands off the coast of New Zealand.

In contrast, there are more than 3,500 species of lizards. These include some well-known types, such as iguanas, geckos, and chameleons, along with some obscure forms, such as the legless worm lizards. Lizards are worldwide in distribution, extending from the tropics to very high latitudes. The largest group among the lizards is the skink family with over 1,000 species. Lizards have come up with a variety of strategies for movement and other life processes. Many race around in high-speed bursts; some even run on two legs. A specialized tropical lizard can run upright across the surface of the water. Some lizards are specialized burrowers that spend much of their life underground, while others have special flaps that allow them to soar through the air over great distances. In addition, many have adopted different techniques to reproduce, such as laying eggs, bearing live young, and even a form of asexual reproduction whereby females virtually produce clones of themselves.

Snakes also are widespread and highly diverse, with around 3,000 species worldwide. They are all without limbs, a feature that also is shared by some of their lizard relatives. Snakes are unique in their ability to move their upper and lower jaws independently. This allows them to open their mouths very wide to swallow large prey, often wider than their own bodies. Some snakes swallow their prey whole while others, such as boas, first squeeze their prey by tightly coiling around them. An entire group of snakes

injects venom into their prey, by squeezing poison out of special sacs and delivering it through punctures caused by their fangs. Many snakes reproduce by laying eggs, but several groups bear live young, including the rattlesnakes. Snakes vary widely in size, ranging from species that are not much larger than an earthworm, to the giant anacondas that can reach lengths as great as 10 m (33 ft).

The fame of the crocodilians seems to be a bit out of proportion to their actual presence in today's world. Perhaps the image of their powerful jaws, or their quick and violent bursts of speed, captures our imagination. Or perhaps it is the vision of a crocodile silently slipping off the riverbank into the water in deadly pursuit of unwary prey. Nevertheless, today there are only 22 species of crocodilians, all of which largely are confined to the tropics and subtropical regions. Crocodiles, alligators, and gharials (which are represented by only one species) are all that remain of the prehistoric crocodilians.

They all are powerful swimmers, with a muscular tail that propels them through the water. They lay eggs in mounds that the female constructs out of vegetation and soil. All crocodilians show a high degree of parental care. Mothers guard the nests and help the hatching process. In some species, particularly among the alligators, the mother continues to protect the young for a year or more, and sometimes they live in extended family groups for even longer.

Among all of the vertebrates, the turtles are an obvious standout. Their special features, such as an upper and lower shell made of bones, are truly astonishing developments among the vertebrates. The success of turtles is demonstrated by the fact that after more than 200 million years of existence, they remain relatively unchanged. Some turtles can withdraw their head and legs and completely enclose them within their shells, sealing themselves off from the outside world. Many are docile, subdued creatures, while others are aggressive and easily provoked. Today there are more than 250 species spread throughout all the continents, ranging from the tropics to high latitudes. Turtles occupy many habitats, from the tortoises in the driest desert areas, to the semiaquatic turtles inhabiting freshwater lakes and swamps, to the sea turtles that travel the world's oceans. All turtles are egg-laying reptiles, depositing their eggs in nests on land that they scoop out with their hind feet.

Similarities between Amphibians and Reptiles

Despite all of the differences between and among amphibians and reptiles, a single feature that traditionally united them in our minds was the notion of their being "cold-blooded." Today, we are not as keen on this term as a description of these animals. In fact, many reptiles can maintain body temperatures as high or higher than humans. Think of a small lizard resting on the sand of a desert or on a hot beach. The body temperatures of these animals are far from cold.

Two sets of terms help us better describe the temperature regulation of amphibians and reptiles. They have to do with how animals warm or cool themselves and how variable their body temperatures are. Animals whose temperatures are regulated by outside sources in the environment are said to be *ectothermic*. This is different from *endothermic* animals, such as mammals and birds, whose temperature is primarily generated from

internal body processes. Mammals and birds also closely regulate their range of internal body temperature, not letting it vary by more than a few degrees during normal activities. This tight control is called *homeothermy*. Most amphibians and reptiles, however, are able to withstand wide ranges of body temperatures and still continue to function. This is called *poikilothermy*.

The ability to withstand such a broad range of internal body temperatures is a common trait shared by many amphibians and reptiles. Sometimes this thermal flexibility can be truly impressive. The same small lizard that exposes itself to hot desert sands also can experience very cold nights and still remain active. The same painted turtle that basks in the warm summer sun also can be seen swimming slowly beneath the ice in the middle of winter. Similarly, it is common to see hundreds of newts swimming around in frozen lakes of the far north.

These and other shared features connect amphibians and reptiles and go some way toward justifying the traditional lumping of these distinct groups of animals. But far beyond shared ancestry and some similarities in behavior and physical structures, the amphibians and reptiles will always be linked in their ability to excite and fascinate children and adults alike.