Frogs

Frogs

History and fossil record

Morphology

Adult morphology

Larval morphology

Ecology

Life history and behavior

Classification

Frogs and humans

The future of frogs

Resources

Frogs are tail-less amphibians (class Amphibia, order Anura). With some 4,800 living species, frogs are the most numerous and best known of amphibians. They are found on all continents except Antarctica (/places/oceans-continents-and-polar-regions/antarctic-physical-geography/antarctica) and are common on many oceanic islands. The terms “frog” and “toad” are derived from early usage in England (/places/britain-ireland-france-and-low-countries/british-and-irish-political-geography/england) and northern Europe (/places/oceans-continents-and-polar-regions/oceans-and-continents/europe), where two families of the order Anura occur. One includes slender, long-legged, smooth-skinned animals that live near water: frogs; the other includes short-legged warty animals that live in fields and gardens: toads. When other kinds of animals of this group were discovered elsewhere, such as tree-frogs, fire-bellied toads, and others, it was realized that these various forms actually represented one major group. This group, the anurans, is now commonly referred to as frogs.

History and fossil record

Frogs and their ancestors are among the most ancient of terrestrial vertebrates. A frog-like fossil animal more than 240 million years old is known from early Triassic rocks of Madagascar (/places/africa/madagascar-political-geography/madagascar). This ancient amphibian, named *Triadobatrachus*, differs from true frogs in having more vertebrae in its spinal column (/medicine/anatomy-and-physiology/anatomy-and-physiology/spinal-column) (14, rather than 5-9) and in having a tail made up of six additional vertebrae. For these and several other differences, it is classified in a different order, the Proanura. By Jurassic times, 208-146 million years ago, such ancestral amphibians had evolved into true frogs, whose skeletal remains are little different from those living today.

Morphology

Frogs are amphibians, a term derived from two Greek words: *amphi* meaning double and *bios* meaning life. The double life of frogs involves living in water and also on land. Because of this amphibious habit, they must have adaptations for each environment. As in other animals that have a separate larval stage and a complex life cycle, frogs have two extremely different morphologies.

Adult morphology

If frogs were not so common and familiar, they would be regarded as among the strangest of vertebrate animals. The typical frog has a broad head with an enormous mouth and protruding eyes. The body is short and plump, and there is no tail. The forelegs are rather short but normal-looking, and are used mainly for propping up the front part of the body and for stuffing food into the mouth. The hind limbs are much larger and more muscular, and have an extra joint that makes them even longer and provides extra power for jumping, which is their major mode of locomotion. Among aquatic frogs, the hind limbs also provide the propulsion for swimming.

The frog skeleton has been evolutionarily reduced. The skull is a framework of bones that hold the braincase, eyes, internal ears, and jaws, while giving support to the jaw muscles. The vertebral column (/medicine/anatomy-and-physiology/anatomy-and-physiology/vertebral-column) has been reduced to only 5-9 body vertebrae, and the caudal (tail) vertebrae have become fused into a single mass, the urostyle. Although the bones of the fore-limbs are relatively normal-looking, those of the hindlimbs are highly modified for jumping. The tibia and fibula are fused into a single rod, and an extra joint has developed from the elongation of some of the foot bones, thus providing a jumping apparatus considerably longer than the torso.

Most frogs have a smooth, obviously moist skin. Even toads, with their warty, seemingly dry skin, have a surface cover that is moist and permeable to liquids and gases. This has advantages and disadvantages, but is necessary for frogs to carry on normal respiration. The

lungs of amphibians are too small and simple in construction to provide adequate gas exchange, and

the skin plays an important role in this regard. A significant amount of oxygen comes into the body via the skin, and as much as half of the carbon dioxide (/science-and-technology/chemistry/compounds-and-elements/carbon-dioxide) produced is released through this covering.

The internal anatomy is broadly similar to that of other vertebrate animals. There is a heart and associated circulatory system (/medicine/anatomy-and-physiology/anatomy-and-physiology/circulatory-system), a brain and nervous system (/medicine/anatomy-and-physiology/anatomy-and-physiology/nervous-system), and a digestive system (/medicine/anatomy-and-physiology/anatomy-and-physiology/digestive-system) made up of esophagus, stomach, and small and large intestines, with the associated liver and other organs. The urinary system is relatively simple, having two kidneys as in most vertebrates. The reproductive system consists of paired ovaries or testes, with associated ducts. As in many vertebrates, the digestive, urinary, and reproductive systems empty through a common posterior chamber, the cloaca.

Larval morphology

Tadpoles, the larval stage of frogs, are adapted to a purely aquatic life. They are seemingly reduced to the essentials, which in this case includes a globular body with a muscular, finned tail. Typically, tadpoles have no bones but rather a simple cartilaginous skull and skeleton. They also have no true teeth, instead having rows of denticles and a beak of keratin (a fingernail-like substance). The globular body is mainly filled with a long, highly coiled intestine.

Ecology

The highly permeable skin of frogs might lead us to expect that they must always have access to water. This is generally true, but not always. It is true that if a common aquatic species, such as a leopard frog (*Rana pipiens*), were to escape from its cage and roam on the floor for a night, it would be little more than a dried-up mummy by the next morning. However, during the millions of years of frog evolution, many species have found ways of adapting to varying water availability in natural habitats. Although many frogs are aquatic, and some never leave the water, there are also desert frogs, tree-frogs, and others that can withstand the drying power of tropical heat for a day or more.

Life history and behavior

Like other amphibians, such as salamanders (order Caudata) and caecilians (order Gymnophiona), most frogs hatch from a shell-less egg into a gilled, water-dwelling, larval stage (a tadpole). After a period of growth they metamorphose into the adult form. Most

species of tadpoles are vegetarians, feeding upon algae and other plant material. All adult frogs, however, are carnivores, most of them feeding upon insects and other invertebrates.

In the temperate zones of the world the breeding season begins in the spring, but the precise time depends upon the species of frog. In much of temperate North America (/places/oceans-continents-and-polar-regions/oceans-and-continents/north-america), for example, the beginning of springtime is proclaimed by the breeding calls of chorus frogs (*Pseudacris* spp.). Their high trills are soon followed by the calls of the spring peeper (*Hyla crucifer*). These may be followed by the rasping calls of the wood frog (*Rana sylvatica*), the leopard frog (*Rana pipiens*), and the green frog (*Rana clamitans*). Then the American toad (*Bufo americanus*) trills in, and when the larger ponds eventually warm up, the bullfrog (*Rana catesbeiana*) begins its booming jug-of-rum calls. As many as 16 different species of frogs have been found calling at various times at a single pond in Florida (/places/united-states-and-canada/us-political-geography/florida).

The males of each frog species have their own distinctive call. It has recently been found that the ear of the female is “tuned” to the call of her own species, so that not only is she not attracted to the calls other species, she may not even hear them! A female carrying eggs will typically approach a calling male of her choice (and of her species), and nudge him. He immediately ceases calling and grasps her around the waist. They enter the water (if they are not already in it), and as she expels eggs from her cloaca, the male sprays sperm over them. Depending upon the species, the eggs may appear in strings, in clusters, or as individual ova.

The eggs are enclosed in a protective jelly coating, and will develop over several days to a week into a tadpole. The tadpole will grow over a period of time (weeks, months, or years, depending upon the species), and ultimately sprouts legs, changes other elements of its external and internal morphology, and emerges as a small replica of the adult.

This sequence is typical of frogs living in temperate regions. In the tropics breeding is often initiated by a change in weather (such as dry to wet), the calling males may be on the moist forest floor or in a tree, the eggs may be laid on foliage or beneath a rock or in a pond, and the tadpole stage may be completed inside the egg capsule, so that froglets appear directly from the egg. In other words, there is enormous variation in breeding habits, particularly in the tropics.

Classification

During the 200 million years of their existence, frogs have been evolving in response to varying environmental conditions. Common elements of their adaptations have given rise to clusters of species that share certain morphological, physiological, and behavioral traits. A system of classification has been established, mostly based on morphological features of adult

frogs and their larvae. In the one presented here, two suborders, five superfamilies, and 21 families are recognized. It should be emphasized, however, that several systems of classification are recognized by scientists.

The families are often distinguished by such characters as the kind and number of vertebrae, the shape of the pectoral girdle (/plants-and-animals/zoology-and-veterinary-medicine/zoology-general/pectoral-girdle), the presence of ribs, the kind and number of limb bones, and other elements. The structure of the pectoral girdle (/plants-and-animals/zoology-and-veterinary-medicine/zoology-general/pectoral-girdle) is an especially distinctive feature that separates large groups of otherwise similar-looking frogs.

The two genera of the family Leiopelmatidae are thought to be relics of an ancient group of frogs. They differ from all other frogs, and are also quite different from each other in habits and distribution, reflecting a long separation (in fact, some taxonomists place the *Ascaphus* frogs in a separate family, Ascaphidae). Members of the genus *Leiopelma* are small terrestrial frogs of New Zealand (/places/australia-and-oceania/australian-and-new-zealand-political-geography/new-zealand), whereas the two *Ascaphus* specias, the “tailed frog” of western North America (/places/oceans-continents-and-polar-regions/oceans-and-continents/north-america), inhabit streams. (The “tail” is actually an extension of the cloaca of males, and is used to place sperm into the cloaca of the female.) The Discoglossidae are another primitive group, made up of Asian and European pond frogs.

Other primitive frogs include the burrowing frog of Mexico (*Rhinophrynus dorsalis*) and a number of highly aquatic frogs, the Pipidae of Africa and South America (/places/oceans-continents-and-polar-regions/oceans-and-continents/south-america). (One of this group, the African clawed frog [*Xenopus laevis*], has escaped from captivity and established wild populations in coastal California (/places/united-states-and-canada/us-political-geography/california).) The spadefoot and parsley frogs (Ascaphidae) of North America (/places/oceans-continents-and-polar-regions/oceans-and-continents/north-america) and Europe are adapted to arid regions. They fall between the “primitive” and “advanced” frogs in structure, and show no close relationship to either. Their larvae are adapted to the rigors of desert life, and have very short periods of aquatic life.

Most of the world’s frogs are included in the modern suborder Neobratrachia, with the superfamily Bufonoidea including several large families such as the Australian Myobatrachidae, the South (/places/united-states-and-canada/miscellaneous-us-geography/south) American Leptodactylidae, and the widespread Hylidae. A number of smaller, specialized families are associated with them because of the common possession of a similarly structured pectoral girdle (known as arciferal).

The superfamily Ranoidea includes the large and widespread family Ranidae (the true or water frogs), the arboreal Rhacophoridae of Asia (/places/oceans-continents-and-polar-regions/oceans-and-continents/asia) and Madagascar (flying frogs and allies), and the sedge

frogs of Africa. Both of the latter appear to be derived from the ranids. The Ranoidea also includes the narrow-mouth toads, or Microhylidae. This widespread family of distinctively shaped ant-eating frogs has a so-called firmasternal pectoral girdle, and does not appear to be closely related to any other frog family, differing especially in their larval morphology. It has been placed only tentatively with the ranoid group.

In general, the species and genera of frogs in any region are relatively easy to recognize on the basis of their external features. These include the skin texture and color, the shape of the pupil of the eye (horizontally elliptic, vertically elliptic, or round), the amount of toe webbing, and the general body proportions, together with the geographic location and habitat. For example, a toad (family Bufonidae) is easily recognized throughout the world because of its warty skin. Water-dwelling frogs (Ranidae) are usually distinguished by their webbed hind feet. Tree-frogs usually have expanded toe-tips, although this can be misleading because some hylids (such as the cricket frogs of North America; genus *Acris*) have taken up a terrestrial existence and lost their climbing pads. Also, there are three quite different families of treefrogs: the Hylidae, which is primarily South American but with some members in North America and northern Eurasia; Centrolenidae, found only in the American tropics; and the Rhacophoridae of Asia, with a few species in Madagascar and Africa. The classification of the treefrogs of Australia (/places/australia-and-oceania/australian-and-new-zealand-political-geography/australia) is still under consideration.

Nevertheless, the skin texture and color, the shape of the pupil of the eye (horizontally elliptic, vertically elliptic, or round), the amount of toe webbing, and the general body proportions together with the geographic location, are useful as local means of identification.

Frogs and humans

Frogs and humans have interacted for many thousands of years. Toads are referred to in ancient writings, as: a “rain of toads,” the “eye of toad” as part of a witch’s brew, and in many other relationships.

Frogs are also used in research, and to teach biology. A core element of many high school and college biology classes in the United States (/places/united-states-and-canada/us-political-geography/united-states) might involve each student dissecting a frog. Millions of leopard frogs have been utilized in this way in schools. By the 1950s, however, it was found that their numbers in the wild had decreased drastically, particularly in the midwestern United States (/places/united-states-and-canada/us-political-geography/united-states). This meant that frogs had to be imported from Canada (/places/united-states-and-canada/canadian-political-geography/canada) and Mexico for use in teaching biology. During the past decade or so the emphasis on dissection has been much reduced, but large numbers of frogs are still used each year in physiological experiments. The frog populations of the Midwest have not recovered, and those of Canada and Mexico have also declined greatly.

Similarly, “frog-legs” used to be a prominent dish in many restaurants. American bullfrogs (*Rana cates-beiana*) of the swamps of Florida and Louisiana (/places/united-states-and-canada/us-political-geography/louisiana) were the major source of this food. However, because of overhunting it became too uncommon to be exploited by frog hunters in the United States (/places/united-states-and-canada/us-political-geography/united-states), and imported legs of *Rana tigrina* and other species from India (/places/asia/indian-political-geography/india) became the major source of frog legs.

More recently, the poison-arrow frogs of tropical America (Dendrobatidae) have become of great interest to pharmaceutical companies. Each species has a unique mix of biochemicals that may have a role to play in the treatment of human diseases. Frogs are useful to humans in various ways, although uncontrolled hunting of them can lead to serious problems for their populations.

Many people have kept pet toads or frogs, but the recent commercial market for captive frogs is primarily in exotic species such as South American horned frogs (*Ceratophrys*), the African “bullfrog” (*Pyxicephalus adspersus*), and brightly colored poison-arrow frogs. These animals are beautiful and interesting pets, but could cause ecological harm if they were to be released and develop wild populations beyond their natural range.

The future of frogs

Judging by recent observations, the prospects for many species of frogs is grim. During the 1990s, numerous species of frogs apparently vanished from nature without any obvious cause of their demise. For example, a newly described, extremely unusual Australian frog, (*Rheobatrachus silus*), could not be found in its only known habitat the following year and has not been seen since. Numerous other Australian frogs have also disappeared. Similarly, the golden toad (*Atelopus zeteki*) of Costa Rica (/places/latin-america-and-caribbean/costa-rican-political-geography/costa-rica), which once occurred in large numbers, has undergone a drastic population collapse. The populations of the Yosemite toad (*Bufo canorus*) in the Sierra Nevada of California have

KEY TERMS

Anurans— A general term for frogs and toads.

Arciferal— Having the coracoid elements of the pectoral girdle free and overlapping.

Denticles— Toothlike structures of keratin found around the mouth of tadpoles.

Firmisternal— Having the coracoid elements fused to the girdle.

plummeted. Similar reports have come from other parts of the world, and there is now an international group of biologists investigating the causes of the apparently simultaneous declines of many species of frogs.

Habitat loss and diseases, like chytridiomycosis, undoubtedly have had a negative impact on frog populations. Some biologists also believe that the cause of the loss of these species may be somehow related to pollution caused by human activities. Emissions of chemicals known as chlorofluourocar-bons, for example, may be causing the stratospheric ozone layer (/science-and-technology/biology-and-genetics/environmental-studies/ozone-layer) to become thinner, allowing greater amounts of ultraviolet energy to reach Earth (/earth-and-environment/geology-and-oceanography/geology-and-oceanography/earth)'s surface. There is some evidence that this environmental change may be a cause of the decline of the boreal toad (*Bufo boreas*) of the northwestern United States. This species breeds in open ponds at high altitude, and the intensified exposure to ultraviolet light may be killing its eggs.

Chemical pollutants may also be spread widely through the atmosphere, or be transported by surface water to places far from their original source of emission. Consequently, trace amounts of pesticides have been found in frogs living far from human populations. Although these poisons do not seem to kill the adults, they may be interfering with reproductive processes, and may be causing unusual deformities in rapidly developing tadpoles and juvenile frogs. Because frogs have such delicate, water-absorbing skin, they may be serving as environmental "canaries." Like the actual canaries that coal miners used to take into the mines as an early warning of the presence of toxic gas, frogs seem to be among the most sensitive indicators of ecological damage caused by toxic chemicals.

Resources

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