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SOOGLOSSUS SECHELLENSIS

Seychelles Frog

An ancestral lineage that dates back 66 million years

SCIENTIFIC NAME:	*Sooglossus sechellensis*
FAMILY:	Sooglossidae
LENGTH	½–¾ in (15–21 mm)
LIFE HISTORY	Terrestrial eggs (5–15 in clumps), tadpoles, and adults; parental care
NOTABLE FEATURE	Female cares for the young tadpoles and froglets by carrying them on her back (they only feed after they have left her)
IUCN RED LIST	Endangered

The Sooglossidae are one of only two anuran families endemic to an archipelago (the other being New Zealand's Leiopelmatidae). They are among the oldest known neobatrachian lineages, having diverged from their closest living relative, India's purple burrowing frogs (Nasikabatrachidae) 66 mya—meaning these frogs survived the asteroid impact that wiped out the dinosaurs. The Seychelles Frog is found on three of the granitic inner islands—comprised of several mountain peaks sitting atop a microcontinental fragment of Gondwana (most of which is submerged around 180 ft/55 m below sea level)—and like other sooglossids has an entirely terrestrial life history.

Despite having no external or middle ear, the Seychelles Frog makes complex vocalizations with at least two different notes—the majority of frogs repeat just a single note. The sound is possibly received through bone conduction in the head and/or forearms and shoulder, vibrations through the body wall, and via the lungs toward the inner ear, or via the opercularis system (unique to amphibians and considered an adaptation to life on land). To attract females, male frogs vocalize from cool, damp patches beneath leaf litter or from cracks and crevices in tree roots or rocks. Eggs are deposited, fertilized, and then guarded by one or possibly both parents. Larvae develop into tadpoles within the egg, and on hatching climb on to the back of the female, where they remain until they metamorphose into froglets just a few millimeters long. Throughout this time, the young do not feed, subsisting solely on the yolk.

Being colored a mixture of browns, and sometimes even pale pink, with dark patches and bands, dotted with orange-tipped tubercles, and often with small patches and dots of blue, the Seychelles Frog perfectly blends into its forest-floor habitat, where it is found in mid- to high-elevation mist, palm, and mixed forest, often adjacent to streams. There is evidence to suggest that these frogs have adapted to historic climate warming, as those from Praslin (1,204 ft/367 m elevation) are found in much lower and drier habitats than frogs from either Silhouette (2,248 ft/740 m) or Mahé (2,969 ft/905 m) in the Seychelles.

→ The Seychelles Frog has a distinct genetic identity that is specific to each of the three islands—Mahé, Silhouette, and Praslin—where it is found. Frogs from Praslin may be the oldest of these three lineages, at an estimated 5.7 million years.

LIFE ON LAND & IN WATER

Living in plants

In areas where ponds and other water bodies are few and far between, but vegetation is abundant, many frogs make use of the smaller collections of water often found in plants. They use these microhabitats both as a refuge and a place to breed and care for their young.

Bromeliads are flowering plants found mainly in the Neotropics. Many are rootless and grow on trees, using leaf axils to collect rainwater and nutrients. A range of frogs from different families use bromeliads as temporary refuges, and around 100 species complete their entire life cycle within these plants. This arrangement may benefit both frogs and the bromeliad: the eggs hatch into tadpoles which can grow in a relatively benign environment free of predators, while the bromeliad gains nutrients from tadpole feces.

← Many frogs, like this slender-legged treefrog (genus *Osteocephalus*) deposit their eggs in water captured within the leaves of tropical plants—phytotelma—which act as nurseries for their developing young.

→ Pitcher plants hold rainwater, and many such reservoirs are used by frogs to provide a stable and secure habitat for their developing tadpoles, like those of the Matang Narrow-mouthed Frog (*Microhyla nepenthicola*).

Many such frogs are tied to specific bromeliad species and have highly restricted distributions. For example, the Itambé Bromeliad Frog (*Crossodactylodes itambe*) is found in only one species of bromeliad that occurs on a single mountain summit in Brazil, and the entire global range of the frog is less than a quarter of a square mile. Dispersal and colonization of new bromeliads is thought to occur after heavy rain, although neither this behavior, nor any life history stages of the Itambé Bromeliad Frog, have ever been observed outside its host plant.

Frogs also breed in other water-holding plants like the pitcher plants. Characteristic of poor soils, these plants increase their nutrient intake by capturing and digesting insects within a leafy, water-holding vessel, or "pitcher." Visual cues, scent, or nectar released by the pitchers attract insects, and a slippery pitcher rim, waxy inner walls, and inward-facing, bar- or hair-like structures prevent them escaping, after which the insects drown and are digested in the fluid-filled pitcher. In North America, Spring Peeper Frogs (*Pseudacris crucifer*) sometimes use pitcher plants as refuges, and benefit by intercepting and consuming insects attracted to the plants.

Being mainly carnivorous, pitcher plants release specific organic chemicals into the pitcher that digest animal matter, making their use as tadpole nurseries hazardous. However, the Borneo Narrow-mouthed Frog (*Microhyla borneensis*)—among the world's smallest at less than ½ in (13 mm)—does use a pitcher plant (*Nepenthes ampullaria*) in which to lay eggs and raise its tadpoles. This relationship is noteworthy, as the frog seemingly exploits the fact that *N. ampullaria* is primarily a detritivore, relying on dead leaves for its nutrients, and therefore provides a relatively safe environment for the frog's tadpoles to grow and develop.

Up in the trees

Living above the ground in trees and bushes (arboreality) has evolved in at least 17 frog families, with three (Centrolenidae, Hylidae, Rachophoridae) comprising almost exclusively arboreal species. This is a good example of convergent evolution, where the same trait evolves separately in different groups, and demonstrates how trees provide a range of useful resources that frogs can exploit.

Among treefrogs, there are a variety of specialisms, with some using vegetation several feet above ground or exploiting tree holes for refuges and breeding, while others have mastered the high canopy but return to lower vegetation to lay eggs in cavities, ground-level pools, foam nests, or on leaves that then drip developing tadpoles into a water body. For example, among the three species of Central American hylid treefrogs within the genus *Cruziohyla*, all deposit eggs overhanging pools of water, with the tadpoles dropping into the water below upon hatching. However, while both the Fringed Leaf Frog (*C. craspedopus*) and Sylvia's Treefrog (*C. sylviae*) lay their eggs immediately above flooded cavities or water-filled hollows in fallen trees, the Splendid Treefrog (*C. calcarifer*) lays its eggs on leaves overhanging larger terrestrial pools and open water bodies.

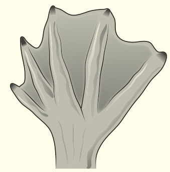
Living in trees and bushes and moving through swaying branches and foliage, presents challenges for frog locomotion, especially in windy conditions. Consequently, sticky toe pads that allow the frogs to adhere to the substrate and climb smooth surfaces have evolved independently in several anuran families.

↗ The Waxy Monkey Frog (*Phyllomedusa sauvagii*) from South America lays its eggs in a nest constructed from leaves.

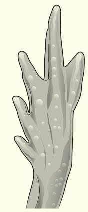
← The Fringed Treefrog (*Cruziohyla craspedopus*) from South America lives high in the forest canopy, but descends to the forest floor to breed in small pools.

Foot adaptation

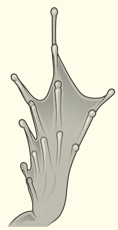
The feet of frogs are highly adapted to their ecology and behavior, from webbed aquatic and semiaquatic, to more robust terrestrial walking and burrowing, arboreal walking, and even gliding.



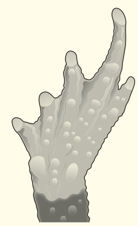
Mwanza Frog
(*Xenopus victorianus*)
Aquatic



Telmatobius chusmisensis
Aquatic



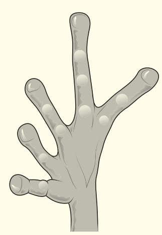
Moyer's River Frog
(*Amietia moyerorum*)
Aquatic



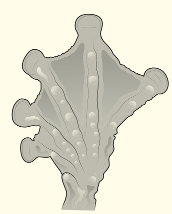
Red-bellied Toad
(*Melanophryniscus dorsalis*)
Terrestrial walker

Eastern Spadefoot
(*Scaphiopus holbrookii*)
Terrestrial burrower

Pseudopaludicola pocoto
Terrestrial/semiaquatic



Lemur Leaf Frog
(*Agalychnis lemur*)
Arboreal walker



Fringe-limbed treefrog
(*Ecnomiohyla miliaria*)
Arboreal glider

Treefrogs like the American Green Treefrog (*Dryophytes cinereus*, see page 64) can comfortably attach to a vertical glass surface without sliding off, even when this is tilted at an acute angle. Microscopic examination of the toe pads has revealed a complex structure that enables treefrogs to maintain their grip. The pads contain hexagonal-shaped cells separated by spaces filled with mucus, which provides a degree of "wet adhesion" and can increase the friction between the toe pad and the substrate. Other methods of hanging on include opposable digits that can grip a branch or leaf, rather like the hand of a primate, as is the case with frogs in the genus *Phyllomedusa*, also known as monkey treefrogs.

Along with gripping onto vertical surfaces, leaves, and branches, arboreal frogs must still traverse their environment to feed and find a mate. Many do this by conventional jumping, walking, or climbing. The Asian treefrogs (or gliding frogs) comprise over 400 species in 21 genera. They are characterized by large webbing on the feet and skin flaps that enable them to glide down from an arboreal vantage point (see Chapter 5).

Living in water

Frogs have successfully exploited a wide range of water bodies, for breeding in particular. These include ephemeral ponds, which cyclically (often seasonally) fill and then dry out, and more expansive habitats such as lakes. Many anurans also live and breed in flowing water like rivers and streams and have evolved physical and behavioral adaptations to thrive in these environments.

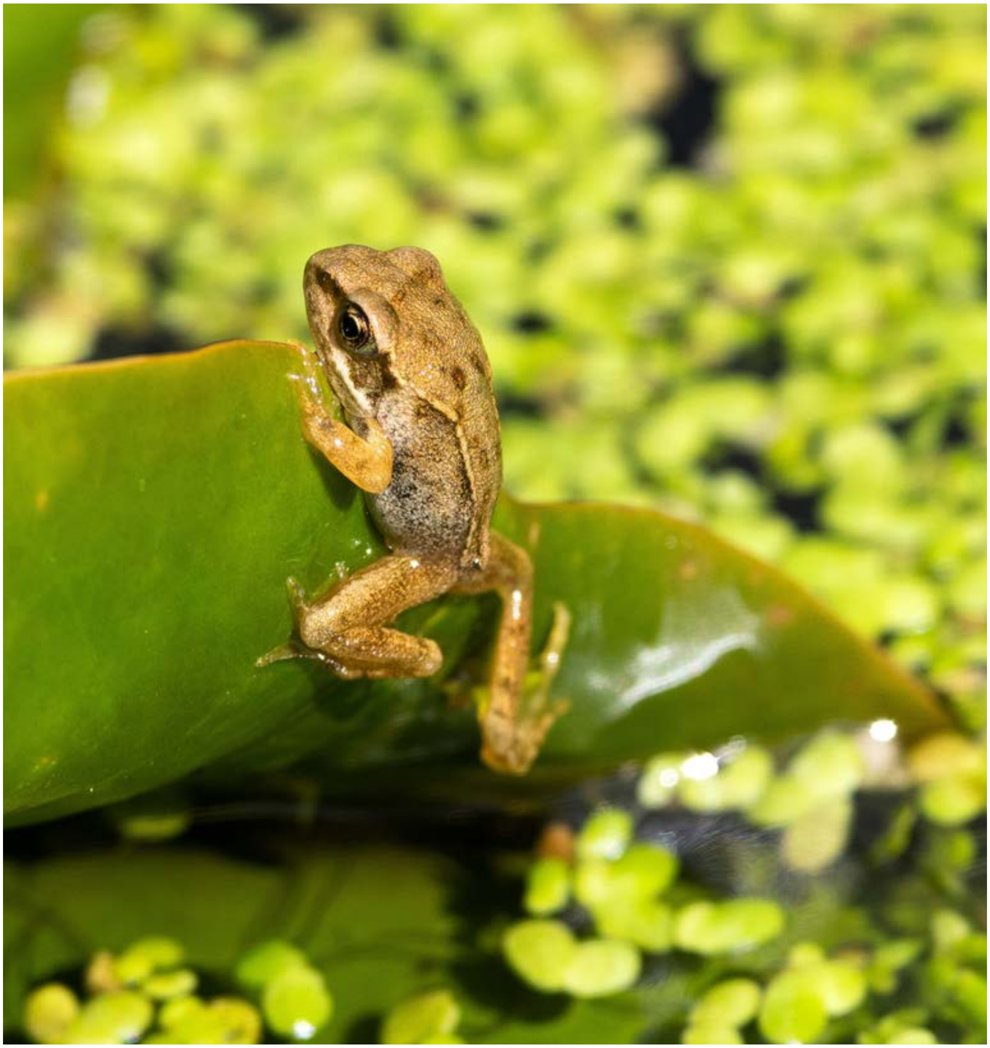
TEMPORARY PONDS

The habitats that frogs have been most successful in exploiting, especially for breeding, are temporary ponds, which fill during the rainy season or after snowmelt, and then slowly desiccate when dry conditions prevail (these are sometimes also called "vernal pools"). These ephemeral water bodies can range in size from small tractor ruts on hillside tracks to large, shallow ponds that form in the depressions between sand dunes. As they are used primarily for breeding and only for a relatively short period, many frogs do not feed while in the water. For example, the "true" frogs and toads in the families Ranidae and Bufonidae mostly prey on terrestrially captured invertebrates. Consequently, they may not forage at all during the breeding period, although this may be over in just a few days.

→ The European green frogs (genus *Pelophylax*) are a group of highly aquatic species that often sit immobile in the water with just their head visible, waiting to ambush insects that may alight on the surface, or to dive down into the water to escape from predators.

Temporary ponds are usually unsuitable for fish, which would be left high and dry when the pond dries out. Although not widely used by adult frogs as places to feed, rain-fed ponds are rapidly colonized by microorganisms, invertebrates, algae, and plants, providing a rich food supply for developing tadpoles. The challenge then for the tadpoles is to complete their development and transform into a froglet before the pool dries out. Frogs deal with this challenge in several ways. One approach is to deposit eggs across different pools. Although some pools—perhaps the majority—may dry out, with the resulting loss of all the young, others might retain water long enough for tadpoles to complete their metamorphosis.

Another strategy (often combined with depositing eggs across different pools) is to breed repeatedly over several years. This requires adult frogs to live long enough to have multiple breeding opportunities throughout their lives. If females lay eggs every year for five years, all the young could be lost due to pond



↖ The Moor Frog (*Rana arvalis*) breeds in boggy pools in northern Europe, and the males can turn bright blue during the mating season.

↗ When frogs like this European Common Frog (*Rana temporaria*) metamorphose, aside from a remnant tail stub and a disproportionately large head, they emerge from the water as a miniature version of the adult.

desiccation in four of those years, but just one successful year may be sufficient to produce enough froglets that survive to adulthood, and thereby sustain the population.

Some tadpoles can even accelerate their development in response to pond desiccation as well as other threats (see Chapter 4). An alternative to laying multiple clutches in different water bodies, and/or over several years, is for the adults to produce fewer offspring but invest more time and effort in caring for them (see also Chapter 4).

PERMANENT WATER BODIES

Permanent and semi-permanent water bodies, such as lakes, reservoirs, spring-fed tarns, or those that form in disused quarries, present different challenges for frogs. Although desiccation risk is reduced, these habitats are much more likely to contain predators. Some frog species may therefore confine their activities to shallower or well-vegetated areas. Alternatively, the tadpoles of those frogs that breed in deeper water often have skin toxins, which make them unpalatable to fish and other potential predators (see Chapter 7).

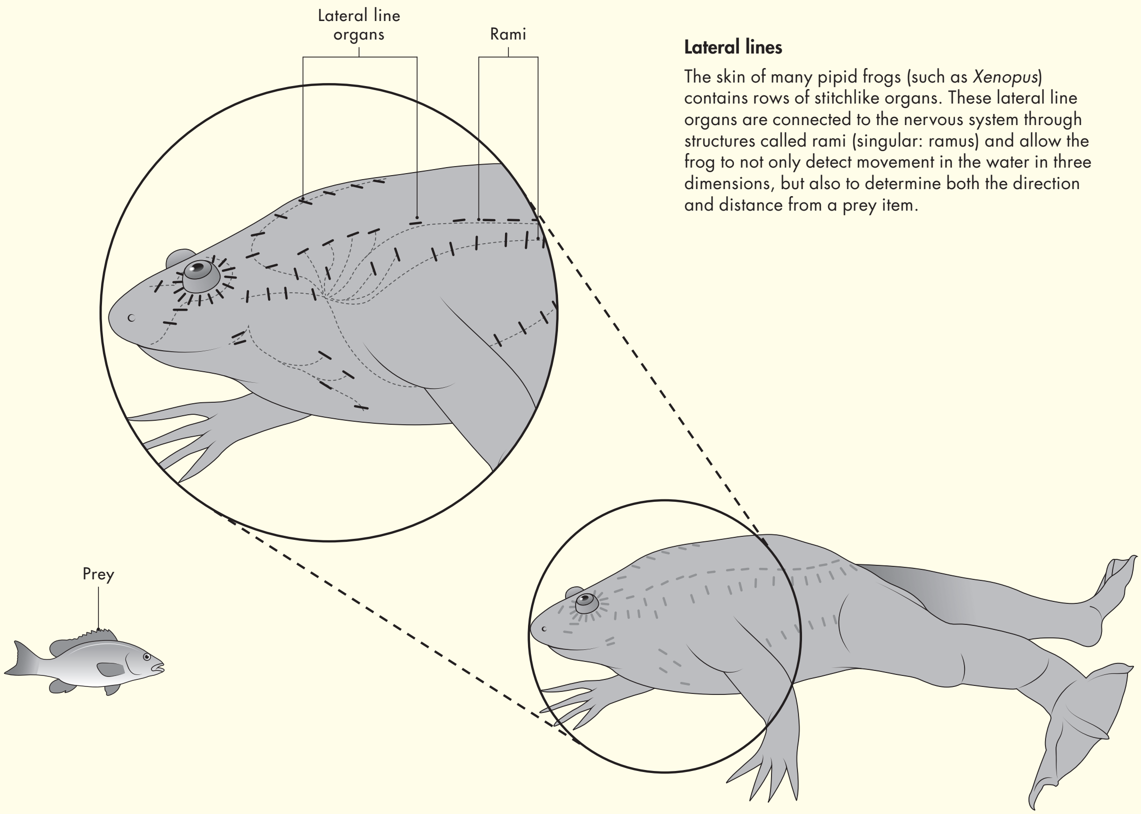
Frogs of the family Pipidae—which comprises African Clawed Frogs and the Surinam Toads of South America—spend almost their entire lives in more permanent ponds and slow-moving streams, so they do feed in the water. The African Clawed Frogs, for example, have smooth skins that are equipped with numerous organs that superficially look like stitches in the skin. These are lateral line organs—similar to those possessed by fish—which can detect the movements of both predator and prey in the water.

↑ Permanent water bodies often also host fish and waterfowl that may make a meal of frogs, tadpoles, and eggs.

Although all aquatic/semi-aquatic frogs have webbed hind feet, these are particularly well-developed in the pipid frogs and provide extra thrust when swimming. These are the only frogs to have claws (or, strictly speaking, claw-like structures) on their hind feet. Most anurans only take live, moving prey, but clawed frogs also take carrion, using their claws to tear apart a larger item of food by holding it in their mouths and bringing their hind legs forward in a kicking motion. The front legs are often used for feeding, pushing food items into the mouth.

As they spend much of the time either buried in mud or suspended at the surface of the water, the eyes of clawed frogs are positioned on the top of the head, enabling them to look out for potential predators (herons and egrets, for example) that may be stalking the pond or river. Although very much adapted to a life in water, even clawed frogs will move short distances across land if they are disturbed or should their pond begin to dry out.

The family Telmatobiidae, endemic to the South American Andes, contains over 60 species of highly aquatic frogs. All known taxa belong to the genus *Telmatobius*, which has two of the largest totally aquatic frogs in the world, the Andes Smooth Frog or Lake Junin Frog (*Telmatobius macrostomus*) and the Titicaca Water Frog (*T. culeus*, see page 66), both of which are found in high-elevation lakes.



Lateral lines

The skin of many pipid frogs (such as *Xenopus*) contains rows of stitchlike organs. These lateral line organs are connected to the nervous system through structures called rami (singular: ramus) and allow the frog to not only detect movement in the water in three dimensions, but also to determine both the direction and distance from a prey item.

FLOWING WATER

Depending on the volume and seasonality of rainfall, streams and rivers can be permanent, or flow for just a short time in a given year. Breeding in these environments presents another challenge to frogs, but several species have adapted their behavior and morphology by anchoring eggs under rocks or within vegetation and evolving tadpoles with suctorial mouthparts that enable them to cling to rocks (see Chapter 4). Additionally, tadpoles adapted to flowing water usually have more streamlined bodies and stronger tail muscles in order to swim within a current.

↑ Frogs that breed in flowing water may have streamlined tadpoles with strong tail muscles for swimming, as well as suckers that allow them to cling to rocks.

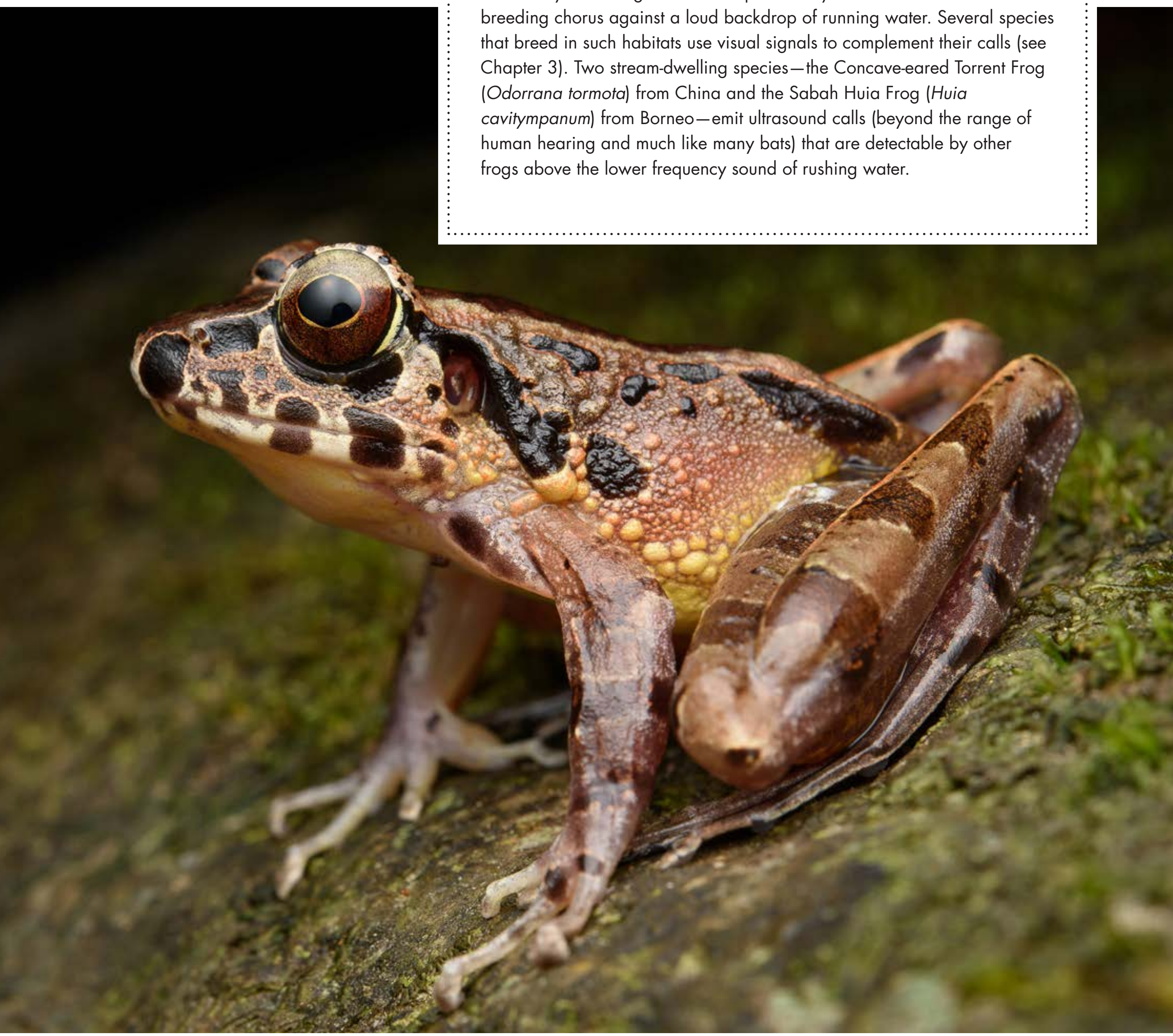
→ The Sabah Huia Frog (*Huia cavitympanum*) is also known as the "hole-in-the-head" frog on account of the tympanic membrane which, unlike other frogs, sits in a recess behind the eye. This adaptation enables it to better detect the ultrasonic calls made by this species.

Alternatively, some species will avoid using the main torrent or river and instead utilize backwaters, or temporary pools that form along the river corridor in times of heavy rain or flood.

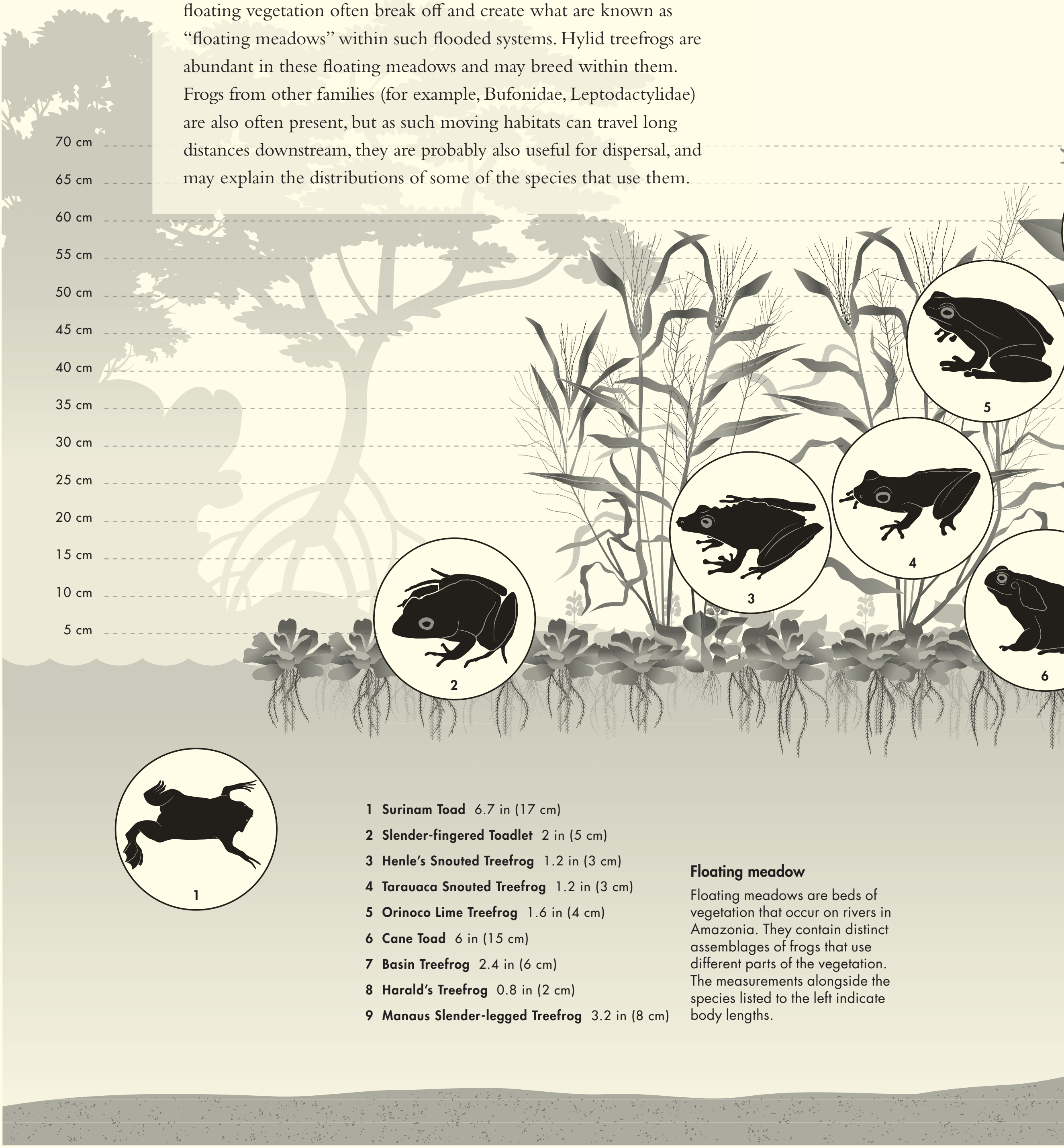
Although fast-flowing water presents some challenges for frogs, the constant churning and aeration of the water means that such torrents are usually well-oxygenated. Until 2007, only two specimens of the Bornean Flat-headed Frog (*Barbourula kalimantanensis*) were known to science, and these had been collected from fast-flowing rivers in the Indonesian state of Kalimantan. Subsequent surveys revealed the existence of two further populations upstream from the original localities, and a recent analysis of the specimens revealed that this species has only tiny remnant lungs. Its flattened body not only helps this aquatic frog to hide in tight spaces between and under rocks, but also provides sufficient surface area over which to absorb oxygen from the turbulent waters where it lives.

HEARING FROG CALLS

Frogs tend to be vocal amphibians and display a complex range of audible calls to defend their territories and to attract mates (see Chapter 3). The challenge with breeding in the vicinity of turbulent streams or waterfalls is that the cascading water creates a complex bioacoustic environment which may mask frog calls. This is particularly the case when males form a breeding chorus against a loud backdrop of running water. Several species that breed in such habitats use visual signals to complement their calls (see Chapter 3). Two stream-dwelling species—the Concave-eared Torrent Frog (*Odorrana tormota*) from China and the Sabah Huia Frog (*Huia cavitympanum*) from Borneo—emit ultrasound calls (beyond the range of human hearing and much like many bats) that are detectable by other frogs above the lower frequency sound of rushing water.



Many parts of the Amazonian rainforest are subject to seasonal flooding which can cause dramatic changes in river levels. Mats of floating vegetation often break off and create what are known as "floating meadows" within such flooded systems. Hylid treefrogs are abundant in these floating meadows and may breed within them. Frogs from other families (for example, Bufonidae, Leptodactylidae) are also often present, but as such moving habitats can travel long distances downstream, they are probably also useful for dispersal, and may explain the distributions of some of the species that use them.



1 **Surinam Toad** 6.7 in (17 cm)
2 **Slender-fingered Toadlet** 2 in (5 cm)
3 **Henle's Snouted Treefrog** 1.2 in (3 cm)
4 **Tarauaca Snouted Treefrog** 1.2 in (3 cm)
5 **Orinoco Lime Treefrog** 1.6 in (4 cm)
6 **Cane Toad** 6 in (15 cm)
7 **Basin Treefrog** 2.4 in (6 cm)
8 **Harald's Treefrog** 0.8 in (2 cm)
9 **Manaus Slender-legged Treefrog** 3.2 in (8 cm)

Floating meadow

Floating meadows are beds of vegetation that occur on rivers in Amazonia. They contain distinct assemblages of frogs that use different parts of the vegetation. The measurements alongside the species listed to the left indicate body lengths.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8
9

Challenges of life on land

To avoid the hottest, driest, and/or coldest periods, many anurans spend hours, days or months secreted in cracks and crevices, hidden on the underside of leaves, or buried in leaf litter, soil, or at the bottom of a pond. They emerge only when conditions are right for them to be active, feed, and reproduce. These behaviors and associated adaptations have allowed frogs to exploit some of the most extreme environments on Earth.

Although all frogs have an association with water and can be found in habitats ranging from tiny puddles to large lakes, the majority spend most of their lives on land. In fact, many frogs do not need freestanding water in which to breed at all. The Coquí Frog (*Eleutherodactylus coquí*) from Puerto Rica, for example, deposits its eggs in damp places. The tadpoles then complete their development within the egg capsule and hatch as fully metamorphosed froglets.

The terrestrial activities of many frogs means that high temperatures present a very real risk of desiccation. In response, frogs will use climate-stable refugia such as tight spaces under rocks and logs or burrows in which to retreat,

← Most frogs in the genus *Eleutherodactylus* lay eggs on land which hatch as fully developed froglets.

↗ In the northern part of their North American range, Eastern Spadefoot Toads (*Scaphiopus holbrookii*) hibernate during winter. In the milder south, they stay active year-round.

emerging only on cool, moist nights to forage. The evolution of such behaviors has allowed frogs to colonize and adapt to seasonal extremes of hot and cold conditions. Couch's Spadefoot Toad (*Scaphiopus couchii*, see page 68) is a well-studied North American anuran with an intriguing suite of adaptations to dry conditions, many of which are convergent with desert-adapted frogs of Africa and Australia, such as the Northern Burrowing Frog (*Neobatrachus aquilonius*, see page 70).

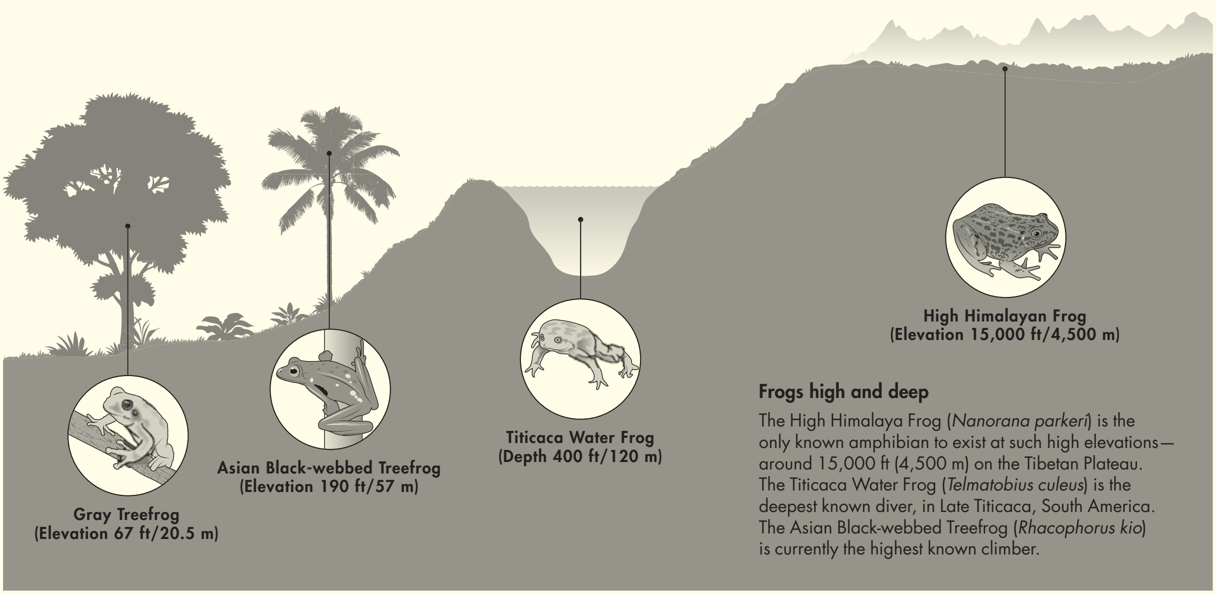
Maintaining hydration when on land is crucial for frogs. Water can be absorbed through the skin, and particularly through the underside when in direct contact with a damp substrate. A patch of skin on the belly in front of the hind legs, sometimes known as the "drink patch" or "pelvic patch," has a rich supply of blood vessels and can absorb water very effectively.

↑ The Australian Water-holding Frog (*Cyclorana platycephala*) is well-adapted to survive dry conditions, and stimulated by rainfall to emerge from their protective burrows to breed.

ESTIVATION AND HIBERNATION

To survive dry desert conditions but remain hydrated, many anurans—for example, Australia's Water-holding Frog (*Cyclorana platycephala*)—store water in their bladder and form waterproof cocoons from layers of shed skin. By estivating in this way, Water-holding Frogs can remain buried for up to three years at a time, and as a result have provided a useful source of water for indigenous peoples in times of drought.

Frogs in more temperate climates avoid colder periods by hibernating, but some go one step further by physiologically adapting to extreme cold, while several North American species can even tolerate freezing (for example, some species of North American chorus frogs, *Pseudacris crucifer, P. triseriata*, and *P. regilla*, and the hylid treefrogs, *Dryophytes versicolor* and *D. chrysoscelis*). However, one frog truly is a cold-habitat survival specialist, and ranges farther north into the Arctic Circle than any other anuran. The Wood Frog (*Lithobates sylvatica*, see page 72), which is found across North America including Alaska and Canada, uses a form of natural antifreeze to survive subzero temperatures during the winter months.



Frogs high and deep

The High Himalaya Frog (*Nanorana parkeri*) is the only known amphibian to exist at such high elevations—around 15,000 ft (4,500 m) on the Tibetan Plateau. The Titicaca Water Frog (*Telmatobius culeus*) is the deepest known diver, in Late Titicaca, South America. The Asian Black-webbed Treefrog (*Rhacophorus kio*) is currently the highest known climber.

↑ Wood Frogs (*Lithobates sylvaticus*) can survive the extremely cold North American winters by using a natural antifreeze within their tissues.

→ The breeding period of the Pacific Treefrog (*Pseudacris regilla*) not only varies considerably in response to prevailing climatic conditions across its western North American range, but also according to elevation, being found up to 10,000 ft (3,048 m) above sea-level.

MANAGING EXTREME CONDITIONS

While frogs have a body temperature that varies according to their immediate thermal environment, which they can manage through behavioral thermoregulation (in other words, they are ectothermic), mammals and birds can control their body temperature internally through their metabolism (they are endothermic). Mammals and birds can therefore remain active in a variety of thermal environments, but anuran activity and metabolism slow under colder conditions, and frogs usually need to avoid extremes of temperature. They do this by seeking a refuge—deep leaf litter, a burrow, the bottom of a deep pond or lake—to wait out the cold and/or hot extremes.

Hibernation infers a period of dormancy in seasonally cold conditions, but as the physiological responses to cold are different between endotherms and ectotherms the term "brumation" is often applied to frogs and other ectotherms. Conversely, the avoidance of seasonally hot, dry conditions is referred to as estivation, and applied more generally across the animal kingdom.

Survival Strategies: Effects and Benefits

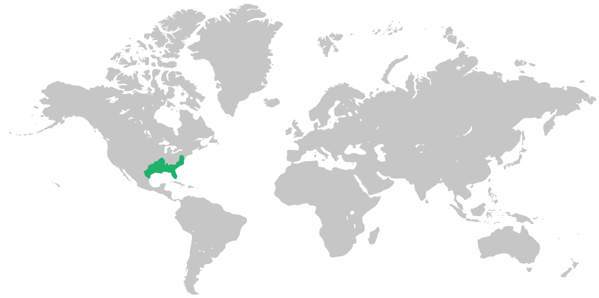
As anuran growth slows during hibernation and/or estivation, distinct "lines of arrested growth" are laid down in the bones rather like the growth rings of trees. By counting these growth rings, it is possible to calculate the number of winters (or hot summers) that a frog has survived, and therefore estimate the animal's age.

The endothermic state in mammals and birds means they can remain active for longer during variable thermal conditions but require regular food to maintain such activity. By synchronizing periods of reduced activity with extremes of thermal environment, frogs can divert the energy otherwise needed to maintain a constant body temperature to reproduction. Along with other ectotherms (like other amphibians, reptiles, fishes, and invertebrates), frogs therefore need less food than mammals and birds, and can often reproduce faster and generate greater numbers of offspring during their periods of peak activity.

→ The Marbled Snout-burrower (*Hemisus marmoratus*) is a subterranean burrowing frog found across sub-Saharan Africa.

↗↗ The Water-holding Frog (*Cyclorana platycaphela*) of Australia survives dry desert conditions by burrowing into the soil and forming a cocoon from shed skin.

→→ Found in France, Spain, and Portugal, in the northern part of its range, the Western Spadefoot Toad (*Pelobates cultripes*) will hibernate in a self-dug burrow to escape colder periods. In hotter, southern regions it burrows in order to estivate.



DRYOPHYTES CINEREUS

American Green Treefrog

Life in the trees

SCIENTIFIC NAME:	*Dryophytes cinereus*
FAMILY:	Hylidae
LENGTH	1½–2½ in (30–60 mm)
LIFE HISTORY	Aquatic eggs (400–2,500 in clumps) and tadpoles; terrestrial arboreal adults
NOTABLE FEATURE	The adhesion of this treefrog's feet can withstand a force of more than 0.6 kg
IUCN RED LIST	Least Concern

As its common name suggests, the American Green Treefrog is a highly arboreal species native to the United States. It inhabits wooded open canopy areas in the vicinity of lakes, ponds, marshland, and backwaters. Coloration varies from bright through to dark green, yellow, brown, and sometimes slate-gray. Most individuals have a yellow, cream, or light-colored lateral stripe, and like many anurans, they can both darken and lighten their skin to match the background habitat.

The thermal ecology of the American Green Treefrog means that it can maintain a higher body temperature than non-arboreal frogs: as much as 97°F (36°C) when in direct sunlight. This is likely due to the production of a mucus barrier, which helps the frog to limit evaporative water loss. Most amphibians have a low tolerance of saline conditions, but intriguingly, coastal populations of American Green Treefrogs have been found breeding in brackish water. The mucus barrier may contribute to this salt tolerance, but the coastal populations also express genes for salt tolerance that are missing in the inland freshwater populations. A further adaptation to such conditions is a shortened larval period, which reduces the time that tadpoles are exposed to high salt levels during their development.

This species is currently expanding its range in the United States, driven primarily by increased flooding due to climate change. Frogs in the expanded range have longer hind legs—indicating greater dispersal ability—than frogs in the historic range.

→ The American Green Treefrog is a chorus breeding frog, meaning that many individuals, male frogs in particular, will congregate at a breeding site to attract a mate. Male frogs will also physically compete with each other by butting or wrestling.

TELMATOBIUS CULEUS

Titicaca Water Frog

Frog with wrinkles

SCIENTIFIC NAME:	*Telmatobius culeus*
FAMILY:	Telmatobatidae
LENGTH	3–5½ in (75–140 mm)
LIFE HISTORY	Aquatic eggs (500 in clumps), tadpoles, and adults
NOTABLE FEATURE	The skin is thrown into a series of fleshy folds resulting in its alternative name of "scrotum frog"
IUCN RED LIST	Endangered

The Titicaca Water Frog is a large aquatic frog found in Lake Titicaca and adjacent water bodies on the border between Bolivia and Peru. It has a background coloration ranging from gray to brown and olive-green, with darker mottling or marbled patterning. When stressed, this frog exudes a sticky, milk-like secretion that fills its skin folds.

The fully aquatic nature of the Titicaca Water Frog is likely due to the extreme environmental conditions surrounding the lake. Situated 12,500 ft (3,800 m) above sea level, Lake Titicaca is subject to strong winds, high UV exposure, and temperatures of 19–64°F (-7–18°C). Temperature fluctuations are much reduced within the lake, and the frog is generally observed within 10 ft (3 m) of the surface where conditions are a more stable 52–57°F (11–14°C), although it has been recorded at depths of 394 ft (120 m) and may use the entire lake water column of 955 ft (291 m).

The Titicaca Water Frog has much-reduced lungs, instead absorbing most of its oxygen across the fleshy folds along its body and legs. These skin folds are richly innervated with blood vessels and maximize the skin surface area for oxygen absorption. In addition, this frog has a much higher count of oxygen-carrying red blood cells than other amphibians and also one of the lowest metabolic rates of any amphibian, both of which further improve its ability to live in cool water.

The species has also been found to carry the chytrid fungus, which has devastated frog populations elsewhere. So far, this fungus does not seem to have affected the Lake Titicaca Water Frogs, possibly because the cool temperature of the lake prevents the fungus becoming widely infectious. Should climate change raise the temperature of the lake, then this situation could change and the chytrid fungus may start causing disease and increased mortality.

→ The Titicaca Water Frog is a high-elevation aquatic specialist, perfectly adapted to absorb oxygen from the water through extensive folds of skin which cover its body. It will sometimes perform "push-ups" to force more water through these skin folds and increase oxygen absorption.

SCAPHIOPUS COUCHII

Couch's Spadefoot Toad

Desert digger

SCIENTIFIC NAME:	*Scaphiopus couchii*
FAMILY:	Pelobatidae
LENGTH	2½-3½ in (55–90 mm)
LIFE HISTORY	Aquatic eggs (3,000 in clumps) and tadpoles; terrestrial adults
NOTABLE FEATURE	Spadelike structures on the hind feet used to dig a burrow
IUCN RED LIST	Least Concern

Adapted to desert regions, arid grasslands, savannah, and dry forest areas of southwest North America, Couch's Spadefoot Toad is so named because of the spade-like structures on the hind feet, which are used for digging burrows in order to see out seasonal hot, dry periods. Couch's Spadefoot tends to be a variable green, yellow, or brown, with darker patches or spots. It can be distinguished from other spadefoot toads by the sickle-like shape of the spade on its hind feet.

Spadefoots can remain burrowed and relatively inactive for ten months of the year, until stimulated to emerge by seasonal thunderstorms that herald the onset of the wet season. Following significant rains, within a day or so of emerging, the toads have mated and each female will lay up to 3,000 eggs in the small, rain-filled pools that form in hollows and streambeds. The eggs can hatch in less than a day and tadpoles complete their development in under two weeks. If the tadpoles become too crowded in desiccating pools, they will start eating each other, thereby ensuring that at least some will make it through to metamorphosis.

Likewise, the adults feast on termites and other insects also stimulated by the rains to emerge and reproduce. An adult Spadefoot can consume more than half of its body weight in insects in a single night of foraging, and this may be all it needs to survive for the next ten months. During the long period of inactivity underground, the metabolic rate drops substantially and the toads lower their rate of breathing to further reduce any water loss. The extremely short period of breeding and activity entirely tied to the rains therefore enables the Spadefoot to survive in desert conditions.

→ Couch's Spadefoot Toad is only rarely above ground—perhaps on no more than 20 nights in a given year. During their time on the surface, they feed and breed before retreating back underground, and they can survive exceptionally dry periods by absorbing moisture from the surrounding soil.

NEOBATRACHUS AQUILONIUS

Northern Burrowing Frog

Life in suspended animation

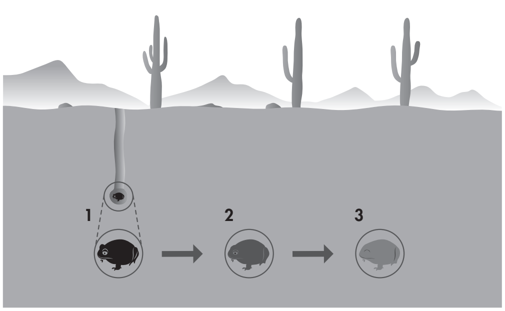
SCIENTIFIC NAME:	*Neobatrachus aquilonius*
FAMILY:	Limnodynastidae
LENGTH	Up to 2½ in (60 mm)
LIFE HISTORY	Aquatic eggs (up to 1,400 in strings) and tadpoles; terrestrial adults
NOTABLE FEATURE	At nearly 3 in (8 cm) long, the tadpoles of this frog are longer than the adult
IUCN RED LIST	Least Concern

The Northern Burrowing Frog is one of many species across several anuran families that has adapted to survive in sparsely vegetated arid and desert environments. These frogs have a rotund body and spade-like structures on the hind feet to aid burrowing, which they do in reverse. They are usually gray to dark brown in color with yellow to orange blotches and mottled markings, and often have a light-colored or yellow stripe running down the back.

Active nocturnally, and only for brief periods following significant rainfall, Northern Burrowing Frogs emerge from burrows to feed and reproduce, with females depositing eggs that hatch and metamorphose within a matter of weeks. Following these periods of explosive activity, frogs estivate to avoid desiccation by digging themselves vertically into damp sandy or sand/clay soils up to 3 ft (1 m) or more in depth. When the surrounding substrate dries, the frog begins to lay down successive layers of shed skin, enveloping the entire body except for the nostrils and forming an increasingly impermeable cocoon. A single layer of skin can be deposited every two or three days, and frogs can survive in this way for many months, with one study having counted 229 layers—giving an estimated average of 20 months spent dormant underground. When cocooned in this way, the frog's metabolic rate drops to about one-fifth of its normal rate. However, frogs respond to the soil conditions, cocooning only when moisture levels fall below the threshold required to maintain hydration from water stored in their bodies.

Adaptable estivation

The Northern Burrowing Frog can adapt to different drying conditions, and may not produce desiccation-proof layers of shed skin unless conditions dictate (1). If the surrounding soil loses moisture, the frog can detect this and begins to slough its skin, forming a barrier between it and the drying soil (2). In the harshest conditions, it can produce more than 200 layers of shed skin and survive in this watertight cocoon for more than two years (3).



→ The Northern Burrowing Frog is known to have four sets of chromosomes (humans have two sets). This additional genetic diversity may mean that it can more readily adapt to climate change.

(continued...)

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