Amphibians

(Class of Vertebrate Animals)

Milford Kirkland

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Amphibian

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Strawberry Poison-dart Frog, *Oophaga pumilio*

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Superclass:	Tetrapoda
Class:	**Amphibia**

Linnaeus, 1758

Subclasses and Orders
Order Temnospondyli – *extinct*
Subclass Lepospondyli – *extinct*
Subclass Lissamphibia
Order Anura
Order Caudata
Order Gymnophiona

Amphibians (class Amphibia, from Amphi- meaning "on both sides" and -bios meaning "life"), such as frogs, salamanders, and caecilians, are ectothermic (or cold-blooded) animals that metamorphose from a juvenile water-breathing form, either to an adult air-breathing form, or to a paedomorph that retains some juvenile characteristics. Mudpuppies, for example, retain juvenile gills in adulthood. The three modern orders of amphibians are Anura (frogs and toads), Caudata (salamanders and newts), and Gymnophiona (caecilians, limbless amphibians that resemble snakes), and in total they numbers approximately 6,500 species. Many amphibians lay their eggs in water. Amphibians are superficially similar to reptiles, but reptiles are amniotes, along with mammals and birds. The study of amphibians is called batrachology.

Amphibians are ecological indicators, and in recent decades there has been a dramatic decline in amphibian populations around the globe. Many species are now threatened or extinct.

Amphibians evolved in the Devonian Period and were top predators in the Carboniferous and Permian Periods, but many lineages were wiped out during the Permian–Triassic extinction. One group, the metoposaurs, remained important predators during the Triassic, but as the world became drier during the Early Jurassic they died out, leaving a handful of relict temnospondyls like *Koolasuchus* and the modern orders of Lissamphibia.

Etymology

Amphibian is derived from the Ancient Greek term ἀμφίβιος *amphíbios* which means both kinds of life, *amphi* meaning “both” and *bio* meaning life. The term was initially used for all kinds of combined natures. Eventually it was used to refer to animals that live both in the water and on land.

Evolutionary history

The first major groups of amphibians developed in the Devonian Period from fish similar to the modern coelacanth and lungfish which had evolved multi-jointed leg-like fins that enabled them to crawl along the sea bottom. These amphibians were as much as one to five meters in length. However, amphibians never developed the ability to live their entire lives on land, having to return to water to lay their shell-less eggs.

In the Carboniferous Period, the amphibians moved up in the food chain and began to occupy the ecological position currently occupied by crocodiles. These amphibians were notable for eating the mega insects on land and many types of fishes in the water. During the Triassic Period, the better land-adapted proto-crocodiles began to compete with amphibians, leading to their reduction in size and importance in the biosphere.

Taxonomic history

Traditionally, amphibians have included all tetrapod vertebrates that are not amniotes. They are divided into three subclasses, of which two are only known as extinct subclasses:

- Subclass Labyrinthodontia† (diverse Paleozoic and early Mesozoic group)
- Subclass Lepospondyli† (small Paleozoic group, sometimes included in the Labyrinthodontia)
- Subclass Lissamphibia (frogs, toads, salamanders, newts, etc.)

Of these only the last subclass includes recent species.

With the phylogenetic classification Labyrinthodontia has been discarded as it is a paraphyletic group without unique defining features apart from shared primitive characteristics. Classification varies according to the preferred phylogeny of the author, whether they use a stem-based or node-based classification. Generally amphibians are defined as the group that includes the common ancestors of all living amphibians (frogs, salamanders and caecilians) and all their descendants. This may also include extinct groups like the temnospondyls (traditionally placed in the subclass "Labyrinthodontia"), and the Lepospondyls. This means that cladistic nomenclature list a large number of basal Devonian and Carboniferous tetrapod groups, undoubtedly were "amphibians" in biology, that are formally placed in Amphibia in Linnaean taxonomy, but not in cladistic taxonomy.

All recent amphibians are included in the subclass Lissamphibia, superorder Salientia, which is usually considered a clade (which means that it is thought that they evolved from a common ancestor apart from other extinct groups), although it has also been suggested that salamanders arose separately from a temnospondyl-like ancestor.

Authorities also disagree on whether Salientia is a Superorder that includes the order Anura, or whether Anura is a sub-order of the order Salientia. Practical considerations seem to favor using the former arrangement now. The Lissamphibia, superorder Salientia, are traditionally divided into three orders, but an extinct salamander-like family, the Albanerpetontidae, is now considered part of the Lissamphibia, besides the superorder Salientia. Furthermore, Salientia includes all three recent orders plus a single Triassic proto-frog, *Triadobatrachus*.

Class **Amphibia**

- Subclass Lissamphibia
    -
        - Family Albanerpetontidae — Jurassic to Miocene (extinct)
    - Superorder Salientia
        - Genus *Triadobatrachus* — Triassic (extinct)
        - Order Anura (frogs and toads): Jurassic to recent — 5,602 recent species in 48 families
        - Order Caudata or Urodela (salamanders, newts): Jurassic to recent — 571 recent species in 9 families
        - Order Gymnophiona or Apoda (caecilians): Jurassic to recent — 174 recent species in 3 families

The actual number of species partly also depends on the taxonomic classification followed, the two most common classifications being the classification of the website AmphibiaWeb, University of California (Berkeley) and the classification by herpetologist Darrel Frost and The American Museum of Natural History, available as the online reference database Amphibian Species of the World. The numbers of species cited above follow Frost.

Respiration

The lungs in amphibians are primitive compared to that of the amniotes, possessing few internal septa, large alveoli and therefore a slow diffusion rate of oxygen into the blood. Ventilation is accomplished by buccal pumping. However, most amphibians are able to exchange gasses with the water or air via their skin. To enable sufficient cutaneous respiration, the surface of their highly vascularized skin must remain moist in order for the oxygen to diffuse at a sufficient rate. Because oxygen concentration in the water increases at both low temperatures and high flow rates, aquatic amphibians in these situations can rely primarily on cutaneous respiration, as in the Titicaca water frog or hellbender salamanders. In air, where oxygen is more concentrated, some small species can rely solely on cutaneous gas exchange, most famously the plethodontid salamanders which have neither lungs nor gills. Many aquatic salamanders and all tadpoles have gills in their larval stage, with some (such as the axolotl) retaining gills as aquatic adults.

Reproduction

Caecilian from the San Antonio zoo

For the purpose of reproduction most amphibians require fresh water. A few (e.g. *Fejervarya raja*) can inhabit brackish water and even survive (though not thrive) in seawater, but there are no true marine amphibians. Several hundred frog species in adaptive radiations (e.g., *Eleutherodactylus*, the Pacific Platymantines, the Australo-Papuan microhylids, and many other tropical frogs), however, do not need any water for breeding in the wild. They reproduce via direct development, an ecological and evolutionary adaptation that has allowed them to be completely independent from free-standing water. Almost all of these frogs live in wet tropical rainforests and their eggs hatch directly into miniature versions of the adult, passing through the tadpole stage within the egg. Reproductive success of many amphibians is dependent not only on the quantity of rainfall, but the seasonal timing.

Several species have also adapted to arid and semi-arid environments, but most of them still need water to lay their eggs. Symbiosis with single celled algae that lives in the jelly-like layer of the eggs has evolved several times. The larvae of frogs (tadpoles or polliwogs) breathe with exterior gills at the start, but soon a pouch is formed that covers the gills and the front legs. Lungs are also formed quite early to assist in breathing. Newt larvae have large external gills that gradually disappear and the larvae of newts are quite similar to the adult form from early age on.

Frogs and toads however have a tadpole stage, which is a totally different organism that is a grazing algae or ongrowth or filtering plankton until a certain size has been reached, where metamorphosis sets in. This metamorphosis lasts typically only 24 hours and consists of:

- The disappearance of the gill pouch, making the front legs visible.
- The transformation of the jaws into the big jaws of predatory frogs (most tadpoles are scraping of algae or are filter feeders)
- The transformation of the digestive system: the long spiral gut of the larva is being replaced by the typical short gut of a predator.
- An adaptation of the nervous system for stereoscopic vision, locomotion and feeding
- A quick growth and movement of the eyes to higher up the skull and the formation of eyelids.
- Formation of skin glands, thickening of the skin and loss of the lateral line system
- An eardrum is developed to lock the middle ear.

The disappearance of the tail is somewhat later (occurs at higher thyroxin levels) and after the tail has been resorbed the animals are ready to leave the water. The material of the tail is being used for a quick growth of the legs. The disappearance of the larval structures is a regulated process called apoptosis.

The transformation of newts when leaving the water is reversible except for the loss of the external gills. When the animals enter the water again for reproduction changes are driven by prolactin, when they return to the land phase by thyroxin

Conservation

The Golden Toad of Monteverde, Costa Rica was among the first casualties of amphibian declines. Formerly abundant, it was last seen in 1989.

Dramatic declines in amphibian populations, including population crashes and mass localized extinction, have been noted in the past two decades from locations all over the world, and amphibian declines are thus perceived as one of the most critical threats to global biodiversity. A number of causes are believed to be involved, including habitat destruction and modification, over-exploitation, pollution, introduced species, climate change, endocrine-disrupting pollutants, destruction of the ozone layer (ultraviolet radiation has shown to be especially damaging to the skin, eyes, and eggs of amphibians), and diseases like chytridiomycosis. However, many of the causes of amphibian declines are still poorly understood, and are a topic of ongoing discussion. A global strategy to stem the crisis has been released in the form of the Amphibian Conservation Action Plan. Developed by over 80 leading experts in the field, this call to action details what would be required to curtail amphibian declines and extinctions over the next 5 years - and how much this would cost. The Amphibian Specialist Group of the World Conservation Union (IUCN) is spearheading efforts to implement a comprehensive global strategy for amphibian conservation. Amphibian Ark is an organization that was formed to implement the ex-situ conservation recommendations of this plan, and they have been working with zoos and aquaria around the world encouraging them to create assurance colonies of threatened amphibians. One such project is the Panama Amphibian Rescue and Conservation Project that built on existing conservation efforts in Panama to create a country-wide response to the threat of chytridiomycosis rapidly spreading into eastern Panama

On January 21, 2008, Evolutionarily Distinct and Globally Endangered (EDGE), as given by chief Helen Meredith, identified nature's most endangered species: "The EDGE amphibians are amongst the most remarkable and unusual species on the planet and yet an alarming 85% of the top 100 are receiving little or no conservation attention." The top 10 endangered species (in the List of endangered animal species) include: the Chinese giant salamander, a distant relative of the newt, the tiny Gardiner's Seychelles, the limbless Sagalla caecilian, South African ghost frogs, lungless Mexican salamanders, the Malagasy rainbow frog, Chile's Darwin frog (Rhinoderma rufum) and the Betic Midwife Toad.

Chapter- 2

Frog (Type of Amphibian)

Frogs **Temporal range: Triassic–present**	
 Australian Green Tree Frog (*Litoria caerulea*)	
Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Subclass:	Lissamphibia
Order:	**Anura** Merrem, 1820
Suborders	
Archaeobatrachia Mesobatrachia Neobatrachia - List of Anuran families	

Native distribution of frogs (in black)

Frogs are amphibians in the order Anura (meaning "tail-less", from Greek *an-,* without + *oura*, tail), formerly referred to as *Salientia* (Latin *salere* (*salio*), "to jump"). Most frogs are characterized by a short body, webbed digits (fingers or toes), protruding eyes and the absence of a tail. Frogs are widely known as exceptional jumpers, and many of the anatomical characteristics of frogs, particularly their long, powerful legs, are adaptations to improve jumping performance. Due to their permeable skin, frogs are often semi-aquatic or inhabit humid areas, but move easily on land. They typically lay their eggs in puddles, ponds or lakes, and their larvae, called tadpoles, have gills and develop in water. Adult frogs follow a carnivorous diet, mostly of arthropods, annelids and gastropods. Frogs are most noticeable by their call, which can be widely heard during the night or day, mainly in their mating season.

The distribution of frogs ranges from tropic to subarctic regions, but most species are found in tropical rainforests. Consisting of more than 5,000 species described, they are among the most diverse groups of vertebrates. However, populations of certain frog species are declining significantly.

A popular distinction is often made between frogs and toads on the basis of their appearance, but this has no taxonomic basis. (Members of the anuran family Bufonidae are called true toads, but many species from other families are also called toads.) In addition to their ecological importance, frogs have many cultural roles, such as in literature, symbolism and religion, and they are also valued as food and as pets.

Etymology and terminology

The name frog derives from Old English *frogga*, (compare Old Norse *frauki*, German *Frosch*, older Dutch spelling *kikvorsch*), cognate with Sanskrit *plava* (frog), probably deriving from Proto-Indo-European *praw* = "to jump".

A distinction is often made between frogs and toads on the basis of their appearance, caused by the convergent adaptation among so-called toads to dry environments; however, this distinction has no taxonomic basis. The only family exclusively given the common name "toad" is Bufonidae, but many species from other families are also called "toads," and the species within the toad genus *Atelopus* are referred to as "harlequin frogs".

Taxonomy

The order *Anura* contains 4,810 species in 33 families, of which the Leptodactylidae (1100 spp.), Hylidae (800 spp.) and Ranidae (750 spp.) are the richest in species. About 88% of amphibian species are frogs.

European Fire-bellied Toad (*Bombina bombina*)

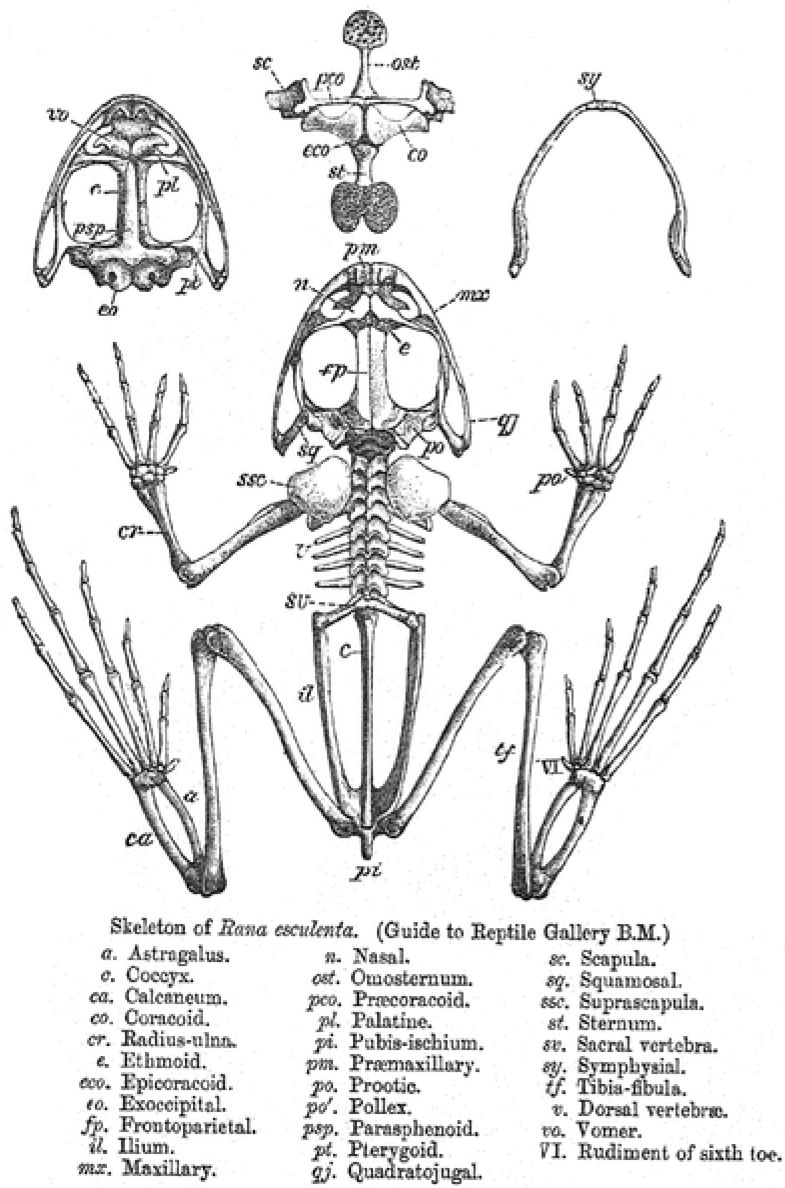
Young American bullfrog found in a stream in New Jersey

The use of the common names "frog" and "toad" has no taxonomic justification. From a taxonomic perspective, all members of the order Anura are frogs, but only members of the family Bufonidae are considered "true toads". The use of the term "frog" in common names usually refers to species that are aquatic or semi-aquatic with smooth and/or moist skins, and the term "toad" generally refers to species that tend to be terrestrial with dry, warty skin. An exception is the fire-bellied toad (*Bombina bombina*): while its skin is slightly warty, it prefers a watery habitat.

Frogs and toads are broadly classified into three suborders: Archaeobatrachia, which includes four families of primitive frogs; Mesobatrachia, which includes five families of more evolutionary intermediate frogs; and Neobatrachia, by far the largest group, which contains the remaining 24 families of "modern" frogs, including most common species throughout the world. Neobatrachia is further divided into the Hyloidea and Ranoidea. This classification is based on such morphological features as the number of vertebrae, the structure of the pectoral girdle, and the morphology of tadpoles. While this classification is largely accepted, relationships among families of frogs are still debated. Future studies of molecular genetics should soon provide further insights to the evolutionary relationships among anuran families.

Some species of anurans hybridise readily. For instance, the Edible Frog (*Rana esculenta*) is a hybrid of the Pool Frog (*R. lessonae*) and the Marsh Frog (*R. ridibunda*). *Bombina bombina* and *Bombina variegata* similarly form hybrids, although these are less fertile, giving rise to a hybrid zone.

Morphology and physiology



Skeleton of *Rana*

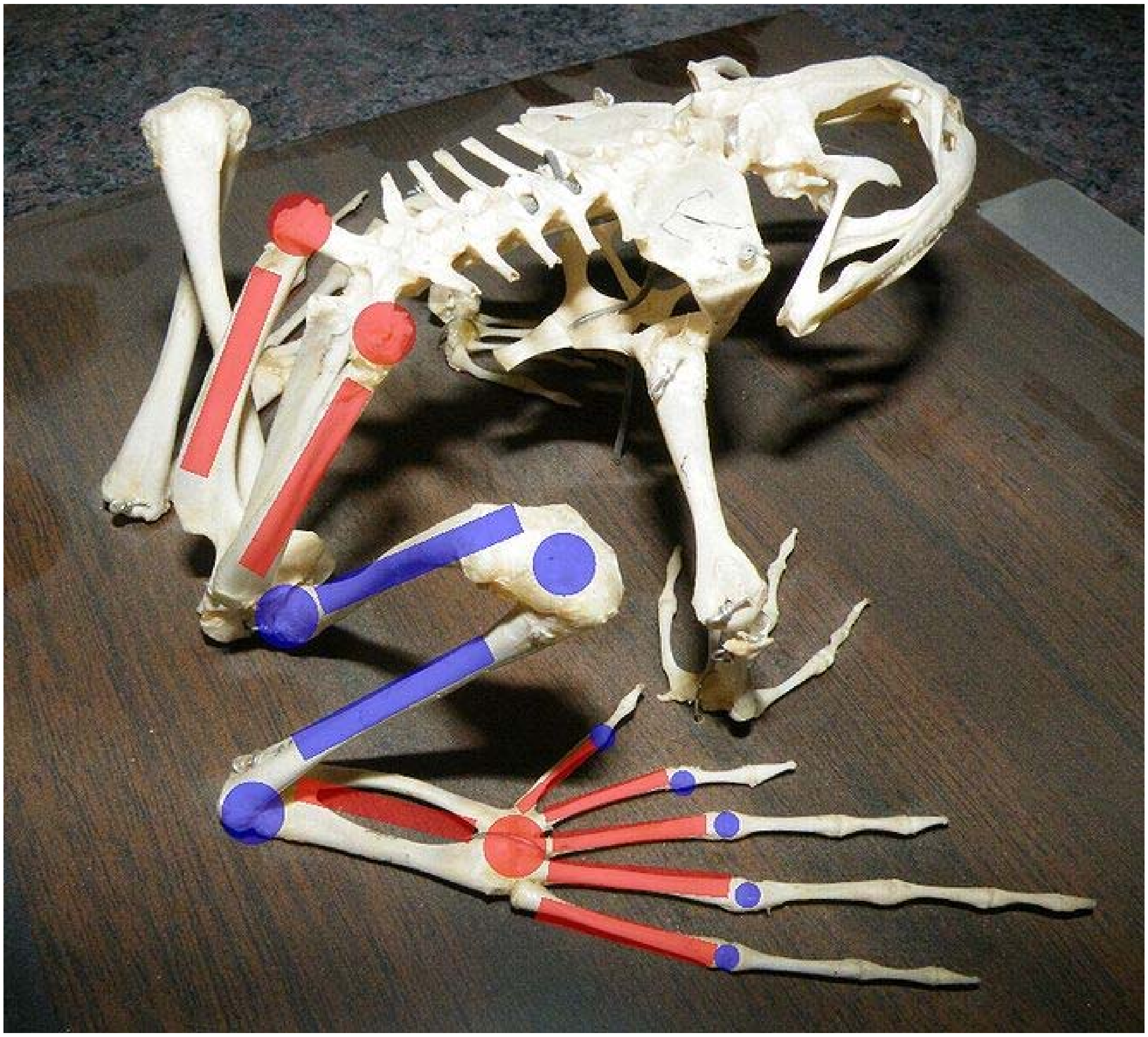
The morphology of frogs is unique among amphibians. Compared with the other two groups of amphibians, (salamanders and caecilians), frogs are unusual because they lack tails as adults and their legs are more suited to jumping than walking. The physiology of frogs is generally like that of other amphibians (and differs from other terrestrial vertebrates) because oxygen can pass through their highly permeable skin. This unique feature allows frogs to "breathe" largely through their skin. Because the oxygen is dissolved in an aqueous film on the skin and passes from there to the blood, the skin must remain moist at all times; this makes frogs susceptible to many toxins in the environment, some of which can similarly dissolve in the layer of water and be passed into their bloodstream. This may be the cause of the decline in frog populations.

Many characteristics are not shared by all of the approximately 5,250 described frog species. However, some general characteristics distinguish them from other amphibians. Frogs are usually well suited to jumping, with long hind legs and elongated ankle bones. They have a short vertebral column, with no more than ten free vertebrae, followed by a fused tailbone (urostyle or coccyx), typically resulting in a tailless phenotype.

Frogs range in size from 10 mm (0.39 in) (*Brachycephalus didactylus* of Brazil and *Eleutherodactylus iberia* of Cuba) to 300 mm (12 in) (goliath frog, *Conraua goliath*, of Cameroon). The skin hangs loosely on the body because of the lack of loose connective tissue. Skin texture varies: it can be smooth, warty or folded. Frogs have three eyelid membranes: one is transparent to protect the eyes underwater, and two vary from translucent to opaque. Frogs have a tympanum on each side of the head, which is involved in hearing and, in some species, is covered by skin. Most frogs have teeth, specifically pedicellate teeth in which the crow is separated from the root by fibrous tissue. Most only have teeth on the edge of the upper jaw (*maxillary teeth*) as well as *vomerine teeth* on the roof of their mouth. They do not have any teeth on their lower jaw, so they usually swallow their food whole. The teeth are mainly used to hold the prey and keep it in place till they can get a good grip on it and swallow their meal, assisted by retracting their eyes into their head. True toads lack any teeth at all, and some species (Pyxicephalus) which prey on relatively large organisms (including mice and other frogs) have cone shaped projections of bone, called odontoid processes, at the front of the lower jaw which function like teeth.

Feet and legs

Tyler's Tree Frog (*Litoria tyleri*) illustrates large toe pads and webbed feet



A bullfrog skeleton, showing elongate limb bones and extra joints. Red marks indicate bones which have been substantially elongated in frogs and joints which have become mobile. Blue indicates joints and bones which have not been modified or only somewhat elongated.

The structure of the feet and legs varies greatly among frog species, depending in part on whether they live primarily on the ground, in water, in trees, or in burrows. Frogs must be able to move quickly through their environment to catch prey and escape predators, and numerous adaptations help them do so.

Many frogs, especially those that live in water, have webbed toes. The degree to which the toes are webbed is directly proportional to the amount of time the species lives in the water. For example, the completely aquatic African dwarf frog (*Hymenochirus sp.*) has fully webbed toes, whereas the toes of White's tree frog (*Litoria caerulea*), an arboreal species, are only a half or a quarter webbed.

Arboreal frogs have "toe pads" to help grip vertical surfaces. These pads, located on the ends of the toes, do not work by suction. Rather, the surface of the pad consists of interlocking cells, with a small gap between adjacent cells. When the frog applies pressure to the toe pads, the interlocking cells grip irregularities on the substrate. The small gaps between the cells drain away all but a thin layer of moisture on the pad, and maintain a grip through capillarity. This allows the frog to grip smooth surfaces, and does not function when the pads are excessively wet.

In many arboreal frogs, a small "intercalary structure" in each toe increases the surface area touching the substrate. Furthermore, since hopping through trees can be dangerous, many arboreal frogs have hip joints that allow both hopping and walking. Some frogs that live high in trees even possess an elaborate degree of webbing between their toes, as do aquatic frogs. In these arboreal frogs, the webs allow the frogs to "parachute" or control their glide from one position in the canopy to another.

Ground-dwelling frogs generally lack the adaptations of aquatic and arboreal frogs. Most have smaller toe pads, if any, and little webbing. Some burrowing frogs have a toe extension—a metatarsal tubercle—that helps them to burrow. The hind legs of ground dwellers are more muscular than those of aqueous and tree-dwelling frogs.

Sometimes during the tadpole stage, one of the animal's rear leg stubs is eaten by a dragonfly nymph. In some of these cases, the full leg grows anyway, and in other cases, it does not, although the frog may still live out its normal lifespan with only three legs. Other times, a parasitic flatworm called *Riberoria trematodes* digs into the rear of a tadpole, where it rearranges the limb bud cells, which sometimes causes the frog to have extra legs.

Jumping

Rainforest Rocket Frog jumping

Frogs are generally recognized as exceptional jumpers, and the best jumper of all vertebrates. The Australian rocket frog, *Litoria nasuta*, can leap over 50 times its body length (5.5 cm), resulting in jumps of over 2 meters. The acceleration of the jump may be up to twice gravity. There are tremendous differences between species in jumping capability, but within a species, jump distance increases with increasing size, but relative jumping distance (body-lengths jumped) decreases.

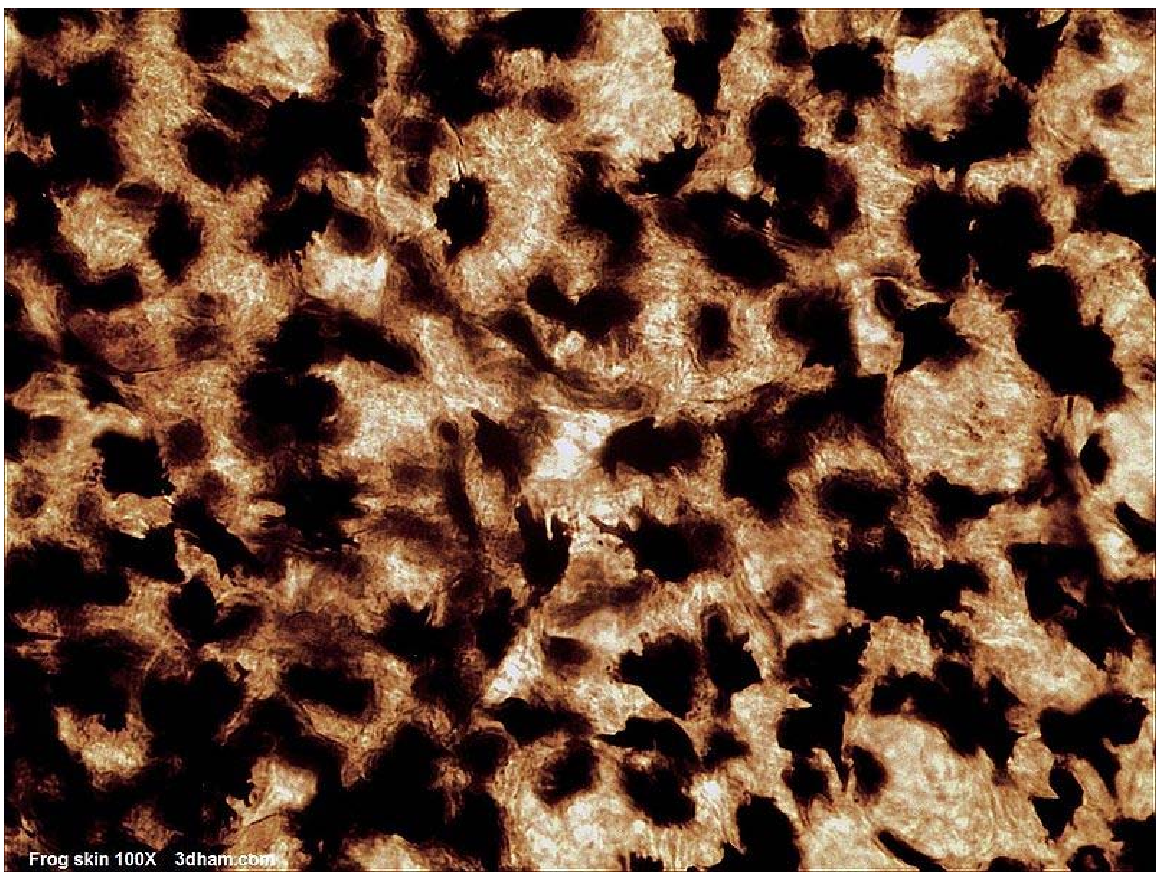
While frog species can use a variety of locomotor modes (running, walking, gliding, swimming, and climbing), more are either proficient at jumping or descended from ancestors who were, with much of the musculo-skeletal morphology modified for this purpose. The tibia, fibula and tarsals have been fused into a single, strong bone, as have the radius and ulna in the forelimbs (which must absorb the impact of landing). The metatarsals have become elongated to add to the leg length and allow the frog to push against the ground for longer during a jump. The illium has elongated and formed a mobile joint with the sacrum which, in specialist jumpers such as Ranids or Hylids, functions as an additional limb joint to further power the leaps. This elongation of the limbs results in the frog being able to apply force to the ground for longer during a jump, which in turn results in a longer, faster jump.

The muscular system has been similarly modified. The hind limbs of the ancestor of frogs presumably contained pairs of muscles which would act in opposition (one muscle to flex the knee, a different muscle to extend it), as is seen in most other limbed animals. However, in modern frogs, almost all muscles have been modified to contribute to the action of jumping, with only a few small muscles remaining to bring the limb back to the starting position and maintain posture. The muscles have also been greatly enlarged, with the muscles involved in jumping accounting for over 17% of the total mass of the frog.

In some extremely capable jumpers, such as the cuban tree frog, the peak power exerted during a jump can exceed what muscle is capable of producing. Currently, it is hypothesized that frogs are storing muscular energy by stretching their tendons like springs, then triggering the release all at once, allowing the frog to increase the energy of its jump beyond the limits of muscle-powered acceleration. A similar mechanism has already been documented in locusts and grasshoppers.

Skin

Pouched Frog (*Assa darlingtoni*) camouflaged against leaf litter.



Microscopic view of frog skin

Many frogs are able to absorb water and oxygen directly through the skin, especially around the pelvic area. However, the permeability of a frog's skin can also result in water loss. Some tree frogs reduce water loss with a waterproof layer of skin. Others have adapted behaviours to conserve water, including engaging in nocturnal activity and resting in a water-conserving position. This position involves the frog lying with its toes and fingers tucked under its body and chin, respectively, with no gap between the body and substrate. Some frog species will also rest in large groups, touching the skin of the neighbouring frog. This reduces the amount of skin exposed to the air or a dry surface, and thus reduces water loss. These adaptations only reduce water loss enough for a predominantly arboreal existence, and are not suitable for arid conditions.

Camouflage is a common defensive mechanism in frogs. Most camouflaged frogs are nocturnal, which adds to their ability to hide. Nocturnal frogs usually find the ideal camouflaged position during the day to sleep. Some frogs have the ability to change colour, but this is usually restricted to shades of one or two colours. For example, White's tree frog varies in shades of green and brown. Features such as warts and skin folds are usually found on ground-dwelling frogs, where a smooth skin would not disguise them effectively. Arboreal frogs usually have smooth skin, enabling them to disguise themselves as leaves.

Certain frogs change colour between night and day, as light and moisture stimulate the pigment cells and cause them to expand or contract.

Poison

Many frogs contain mild toxins that make them unpalatable to potential predators. For example, all toads have large poison glands—the parotoid glands—located behind the eyes, on the top of the head. Some frogs, such as some poison dart frogs, are especially toxic. The chemical makeup of toxins in frogs varies from irritants to hallucinogens, convulsants, nerve poisons, and vasoconstrictors. Many predators of frogs have adapted to tolerate high levels of these poisons. Others, including humans, may be severely affected.

Oophaga pumilio, a poison dart frog, contains numerous alkaloids which deter predators

Some frogs obtain poisons from the ants and other arthropods they eat; others, such as the Australian Corroboree Frogs (*Pseudophryne corroboree* and *Pseudophryne pengilleyi*), can manufacture an alkaloid not derived from their diet. Some native people of South America extract poison from the poison dart frogs and apply it to their darts for hunting, although few species are toxic enough to be used for this purpose. It was previously a misconception the poison was placed on arrows rather than darts. The common name of these frogs was thus changed from "poison arrow frog" to "poison dart frog" in the early 1980s. Poisonous frogs tend to advertise their toxicity with bright colours, an adaptive strategy known as aposematism. There are at least two non-poisonous species of frogs in tropical America (*Eleutherodactylus gaigei* and *Lithodytes lineatus*) that mimic the colouration of dart poison frogs' coloration for self-protection (Batesian mimicry).

Because frog toxins are extraordinarily diverse, they have raised the interest of biochemists as a "natural pharmacy". The alkaloid epibatidine, a painkiller 200 times more potent than morphine, is found in some species of poison dart frogs. Other chemicals isolated from the skin of frogs may offer resistance to HIV infection. Arrow and dart poisons are under active investigation for their potential as therapeutic drugs.

The skin secretions of some toads, such as the Colorado River toad and cane toad, contain bufotoxins, some of which, such as bufotenin, are psychoactive, and have therefore been used as recreational drugs. Typically, the skin secretions are dried and smoked. Skin licking is especially dangerous, and appears to constitute an urban myth.

Respiration and circulation

The skin of a frog is permeable to oxygen and carbon dioxide, as well as to water. There are a number of blood vessels near the surface of the skin. When a frog is underwater, oxygen is transmitted through the skin directly into the bloodstream. On land, adult frogs use their lungs to breathe. Their lungs are similar to those of humans, but the chest muscles are not involved in respiration, and there are no ribs or diaphragm to support breathing. Frogs breathe by taking air in through the nostrils (which often have valves which close when the frog is submerged), causing the throat to puff out, then compressing the floor of the mouth, which forces the air into the lungs. In August 2007 an aquatic frog named *Barbourula kalimantanensis* was discovered in a remote part of Indonesia. The Bornean Flat-headed Frog (*B. kalimantanensis*) is the first species of frog known to science without lungs.

Frogs are known for their three-chambered heart, which they share with all tetrapods except birds, crocodilians and mammals. In the three-chambered heart, oxygenated blood from the lungs and de-oxygenated blood from the respiring tissues enter by separate atria, and are directed via a spiral valve to the appropriate vessel—aorta for oxygenated blood and pulmonary artery for deoxygenated blood. This special structure is essential to keeping the mixing of the two types of blood to a minimum, which enables frogs to have higher metabolic rates, and to be more active than otherwise.

Some species of frog have remarkable adaptations that allow them to survive in oxygen deficient water. The lake titicaca frog (*Telmatobius culeus*) is one such species and to survive in the poorly oxygenated waters of Lake Titicaca it has incredibly wrinkly skin that increases its surface area to enhance gas exchange. This frog will also do 'push-ups' on the lake bed to increase the flow of water around its body.

Digestion and excretion

The frog's digestive system begins with the mouth. Frogs have teeth along their upper jaw called the maxillary teeth, which are used to grind food before swallowing. These teeth are very weak, and cannot be used to catch or harm agile prey. Instead, the frog uses its sticky tongue to catch food (such as flies or other insects). The food then moves through the esophagus into the stomach. The food then proceeds to the small intestine (duodenum and ileum) where most digestion occurs. Frogs carry pancreatic juice from the pancreas, and bile (produced by the liver) through the gallbladder from the liver to the small intestine, where the fluids digest the food and extract the nutrients. When the food passes into the large intestine, the water is reabsorbed and wastes are routed to the cloaca. All wastes exit the body through the cloaca and the cloacal vent.

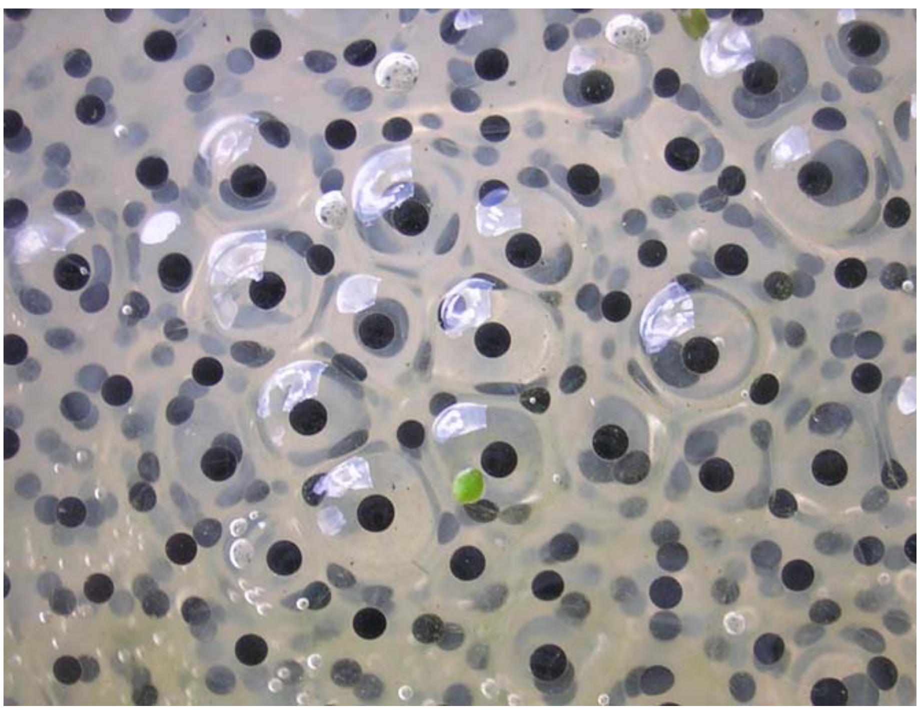
Nervous system

The frog has a highly developed nervous system which consists of a brain, spinal cord and nerves. Many parts of the frog's brain correspond with those of humans. The medulla oblongata regulates respiration, digestion, and other automatic functions. Muscular coordination and posture are controlled by the cerebellum. The relative size of the cerebrum of a frog is much smaller than that of a human. Frogs have ten cranial nerves (nerves which pass information from the outside directly to the brain) and ten pairs of spinal nerves (nerves which pass information from extremities to the brain through the spinal cord). By contrast, all amniotes (mammals, birds and reptiles) have twelve cranial nerves. Frogs do not have external ears; the eardrums (tympanic membranes) are directly exposed. As in all animals, the ear contains semicircular canals which help control balance and orientation. Due to their short cochlea, frogs use electrical tuning to expand their range of audible frequencies.

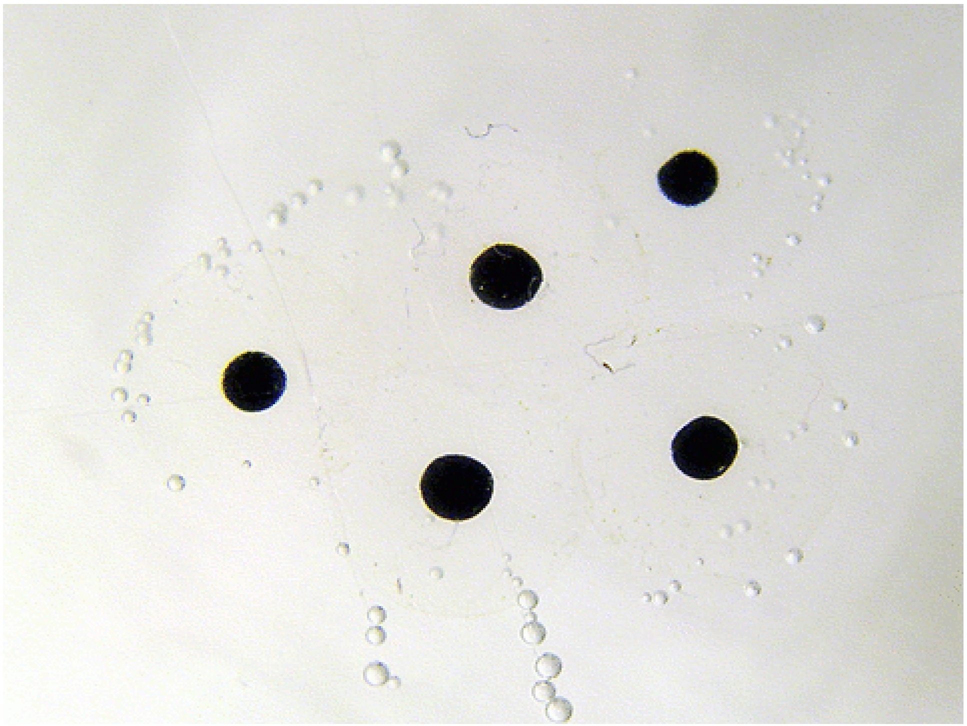
Natural history

The life cycle of frogs, like that of other amphibians, consists of four main stages: egg, tadpole, metamorphosis and adult. The reliance of frogs on an aquatic environment for the egg and tadpole stages gives rise to a variety of breeding behaviours that include the well-known mating calls used by the males of most species to attract females to the bodies of water that they have chosen for breeding. Some frogs also look after their eggs—and in some cases even the tadpoles—for some time after laying.

Life cycle



Frogspawn



Frogspawn development

Tadpole of Haswell's Froglet (*Paracrinia haswelli*)

The life cycle of a frog starts with an egg. A female generally lays gelatinous egg masses containing thousands of eggs, in water. Each anuran species lays eggs in a distinctive, identifiable manner. An example are the long strings of eggs laid by the common American toad. The eggs are highly vulnerable to predation, so frogs have evolved many techniques to ensure the survival of the next generation. In colder areas the embryo is black to absorb more heat from the sun, which speeds up the development. Most commonly, this involves synchronous reproduction. Many individuals will breed at the same time, overwhelming the actions of predators; the majority of the offspring will still die due to predation, but there is a greater chance some will survive. Another way in which some species avoid the predators and pathogens eggs are exposed to in ponds is to lay eggs on leaves above the pond, with a gelatinous coating designed to retain moisture. In these species the tadpoles drop into the water upon hatching. The eggs of some species laid out of water can detect vibrations of nearby predatory wasps or snakes, and will hatch early to avoid being eaten. Some species, such as the Cane Toad (*Bufo marinus*), lay poisonous eggs to minimise predation. While the length of the egg stage depends on the species and environmental conditions, aquatic eggs generally hatch within one week. Other species go through their whole larval phase inside the eggs or the mother, or they have direct development. Unlike salamanders and newts, frogs and toads never become sexually mature while still in their larval stage.

Eggs hatch and continue life as tadpoles (occasionally known as polliwogs), which typically have oval bodies and long, vertically flattened tails. At least one species (Nannophrys ceylonensis) has tadpoles that are semi-terrestrial and live among wet rocks, but as a general rule, free living larvae are fully aquatic. They lack eyelids and have a cartilaginous skeleton, a lateral line system, gills for respiration (external gills at first, internal gills later) and tails with dorsal and ventral folds of skin for swimming. From pretty early onward they develop a gill pouch that covers the gills and the front legs and also the lungs are developed in an early stage as an accessory breathing organ. Some species which go through the metamorphosis inside the egg and hatch to small frogs never develop gills, instead there are specialised areas of skin that takes care of the respiration. Tadpoles also lack true teeth, but the jaws in most species usually have two elongate, parallel rows of small keratinized structures called keradonts in the upper jaw while the lower jaw has three rows of keradonts, surrounded by a horny beak, but the number of rows can be lower or absent, or much higher. Tadpoles are typically herbivorous, feeding mostly on algae, including diatoms filtered from the water through the gills. Some species are carnivorous at the tadpole stage, eating insects, smaller tadpoles, and fish. Cannibalism has been observed among tadpoles. Early developers who gain legs may be eaten by the others, so the late bloomers survive longer. This has been observed in England in the species *Rana temporaria* (common frog).

Tadpoles are highly vulnerable to predation by fish, newts, predatory diving beetles and birds such as kingfishers. Poisonous tadpoles are present in many species, such as Cane Toads. The tadpole stage may be as short as a week, or tadpoles may overwinter and metamorphose the following year in some species, such as the midwife toad (*Alytes obstetricans*) and the common spadefoot (*Pelobates fuscus*). In the Pipidae, with the exception for Hymenochirus, the tadpoles have paired anterior barbels which make them resemble small catfish.

With the exception of the base of the tail, where a few vertebral structures develop to give rise to the urostyle later in life, the tail lacks the completely solid, segmental, skeletal elements of cartilage or bony tissue that are so typical for other vertebrates, although it does contain a notochord

At the end of the tadpole stage, frogs undergo metamorphosis, in which they undergo a transition into the adult form. This metamorphosis last typically only 24 hours and consists of:

Larva of the common frog *Rana temporaria* a day before metamorphisis

Common frog - Metamorphosis stage. Notice the deformed jaws, large eyes and the remains of the gill pouch.

Young frog with tail remains after metamorphosis

Adult leopard frog

- The disappearance of the gill pouch, making the front legs visible.
- The transformation of the jaws into the big jaws of predatory frogs (most tadpoles are scraping of algae or are filter feeders)
- The transformation of the digestive system: the long spiral gut of the larva is being replaced by the typical short gut of a predator.
- An adaptation of the nervous system for stereoscopic vision, locomotion and feeding
- A quick growth and movement of the eyes to higher up the skull and the formation of eyelids.
- Formation of skin glands, thickening of the skin and loss of the lateral line system
- An eardrum is developed to lock the middle ear.

The disappearance of the tail is somewhat later (occurs at higher thyroxin levels) and after the tail has been resorbed the animals are ready to leave the water. The material of the tail is being used for a quick growth of the legs. The disappearing of the larval structures is a regulated process called apoptosis. tail.

Incident of frog cannibalism

After metamorphosis, young adults may leave the water and disperse into terrestrial habitats, or continue to live in the aquatic habitat as adults. Almost all species of frogs are carnivorous as adults, eating invertebrates such as arthropods, annelids and gastropods. A few of the larger species may eat prey such as small mammals, fish and smaller frogs. Some frogs use their sticky tongues to catch fast-moving prey, while others capture their prey and force it into their mouths with their hands. However, there are a very few species of frogs that primarily eat plants. Adult frogs are themselves preyed upon by birds, large fish, snakes, otters, foxes, badgers, coatis, and other animals. Frogs are also eaten by people.

Frogs and toads can live for many years; though little is known about their life span in the wild, captive frogs and toads are recorded living up to 40 years.

Frogs from temperate climates hibernate through the winter, and 4 species are known to freeze during this time, most notably Rana sylvatica.

Reproduction of frogs

Once adult frogs reach maturity, they will assemble at a water source such as a pond or stream to breed. Many frogs return to the bodies of water where they were born, often resulting in annual migrations involving thousands of frogs. In continental Europe, a large proportion of migrating frogs used to die on roads, before special fences and tunnels were built for them.

Male and female Common toad (*Bufo bufo*) in amplexus

A Male and Female common toad in amplexus. The black strands are eggs released into open water minutes after birth.

Once at the breeding ground, male frogs call to attract a mate, collectively becoming a chorus of frogs. The call is unique to the species, and will attract females of that species. Some species have satellite males who do not call, but intercept females that are approaching a calling male.

The male and female frogs then undergo amplexus. This involves the male mounting the female and gripping her (sometimes with special nuptial pads) tightly. Fertilization is external: the egg and sperm meet outside of the body. The female releases her eggs, which the male frog covers with a sperm solution. The eggs then swell and develop a protective coating. The eggs are typically brown or black, with a clear, gelatin-like covering.

Most temperate species of frogs reproduce between late autumn and early spring. In the UK, most common frog populations produce frogspawn in February, although there is wide variation in timing. Water temperatures at this time of year are relatively low, typically between four and 10 degrees Celsius. Reproducing in these conditions helps the developing tadpoles because dissolved oxygen concentrations in the water are highest at cold temperatures. More importantly, reproducing early in the season ensures that appropriate food is available to the developing frogs at the right time.

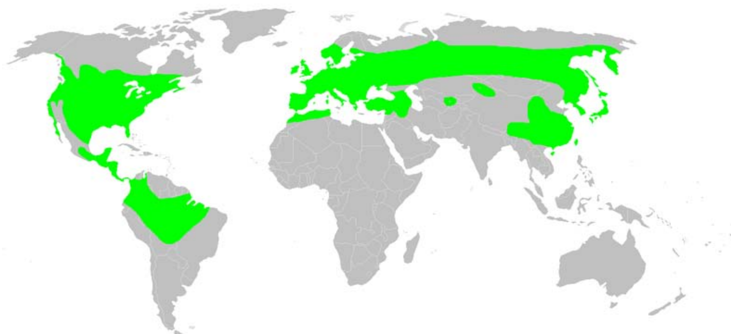
Chapter- 3

Salamander (Type of Amphibian)

Salamanders Temporal range: Jurassic–present

Spotted Salamander, *Ambystoma maculatum*

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Subclass:	Lissamphibia
Order:	**Caudata** Scopoli, 1777
Suborders	
Cryptobranchoidea Salamandroidea Sirenoidea	



Native distribution of salamanders (in green)

Salamander is a common name of approximately 500 species of amphibians. They are typically characterized by their slender bodies, short noses, and long tails. All known fossils and extinct species fall under the order **Caudata**, while sometimes the extant species are grouped together as the **Urodela**. Most salamanders have four toes on their front legs and five on their rear legs. Their moist skin usually makes them reliant on habitats in or near water, or under some protection (e.g., moist ground), often in a wetland. Some salamander species are fully aquatic throughout life, some take to the water intermittently, and some are entirely terrestrial as adults. Unique among vertebrates, they are capable of regenerating lost limbs, as well as other body parts.

Characteristics

Mature salamanders generally have a primitive tetrapod body form similar to that of lizards, with slender bodies, long tails, and four limbs. However, like some lizards, many species of salamander have reduced or absent limbs, giving them a more eel-like appearance. Most species have limbs with four toes on the forelimbs, and five on the hind limbs, and lack claws. Salamanders are often brightly colored, either in both sexes throughout the year, or only in the males, especially during the breeding season. However, the species dwelling entirely underground are often white or pink, lacking any skin pigment.

Many salamanders are relatively small, but there are definite exceptions. They range in size from the minute salamanders, with a total length of 2.7 centimetres (1.1 in), including the tail, to the Chinese giant salamander which reaches 1.8 metres (5.9 ft) and weighs up to 65 kg (140 lb). Most, however, are between 10 centimetres (3.9 in) and 20 centimetres (7.9 in) in length. Salamanders regularly shed the outer layer of their skin (the epidermis) as they grow, and then eat the resulting slough.

A fire salamander in Mount Olympus National Park, Greece

Respiration differs among the different species of salamanders. Species that lack lungs respire through gills. In most cases, these are external gills, visible as tufts on either side of the head, although the amphiumas have internal gills and gill slits. Some salamanders that are terrestrial have lungs that are used in respiration, although these are simple and sac-like, unlike the more complex organs found in mammals. Many species, such as the olm, have both lungs and gills as adults.

Some terrestrial species lack both lungs and gills and perform gas exchange through their skin, a process known as valerian respiration in which the capillary beds are spread throughout the epidermis, and inside the mouth. Even some species with lungs can respire through the skin in this manner.

The skin of salamanders secretes mucus, which helps keep the animal moist when on dry land, and maintains their salt balance while in water, as well as providing a lubricant during swimming. Salamanders also secrete poison from glands in their skin, and some additionally have skin glands for secreting courtship pheromones.

Hunting is yet another unique aspect of salamanders. In the lungless salamanders, muscles surrounding the hyoid bone contract to create pressure and actually "shoot" the hyoid bone out of the mouth along with the tongue. The tip of the tongue is composed of a mucus which creates a sticky end to which the prey is captured. Muscles in the pelvic region are used in order to reel the tongue and the hyoid back to its original position.

Many of the highly aquatic species, however, have no muscles in the tongue, and do not use it for capturing prey, while most other species have a mobile tongue, but without the adaptations to the hyoid bone. Most species of salamander have small teeth in both the upper and lower jaws. Unlike frogs, even the larvae of salamanders possess these teeth.

To find their prey, salamanders use trichromatic color vision in the ultraviolet range based on two photoreceptor types maximally sensitive around 450 nm, 500 nm and 570 nm. Permanently subterranean salamanders have reduced eyes, which may even be covered by a layer of skin. The larvae, and the adults of some highly aquatic species, also have a lateral line organ, similar to that of fish, which can detect changes in water pressure. Salamanders have no external ear, and only a vestigial middle ear.

Salamanders will use tail autotomy to escape predators. Their tail will drop off and wriggle around for a little while, and the salamanders will either run away or stay still enough to not be noticed while the predator is distracted. Salamanders routinely regenerate complex tissues. Within only a few weeks of losing a piece of limb, a salamander perfectly reforms the missing structure.

Distribution

Salamanders split off from the other amphibians during the Mid to Late Permian, and initially were similar to modern members of the Cryptobranchoidea. Their resemblance to lizards is the result of symplesiomorphy, their common retention of the primitive tetrapod body plan, and they are no more closely related to lizards than they are to mammals – or to birds for that matter. Their nearest relatives are the frogs and toads, within Batrachia.

Caudates are found on all continents except for Australia, Antarctica, and most of Africa. One-third of the known salamander species are found in North America. The highest concentration of these is found in the Appalachian Mountains region. Species of salamander are numerous and found in most moist or arid habitats in the northern hemisphere. They usually live in or near brooks, creeks, ponds, and other moist locations.

Development

The life history of salamanders is similar to that of other amphibians such as frogs and toads. Most species fertilize the eggs internally, with the male depositing a sac of sperm in the female's cloaca. The most primitive salamanders – those grouped together as the Cryptobranchoidea – instead exhibit external fertilisation. The eggs are laid in a moist environment, often a pond, but sometimes moist soil, or inside bromeliads. Some species are ovoviviparous, with the female retaining the eggs inside her body until they hatch.

A larval stage follows in which the organism is fully aquatic or land dwelling, and possesses gills. Depending on species, the larval stage may or may not possess legs. The larval stage may last anything from days to years, depending on the species. Some species (such as Dunn's Salamander) exhibit no larval stage at all, with the young hatching as miniature versions of the adult.

Neoteny has been observed in all salamander families, in which an individual may retain gills into sexual maturity. This may be universally possible in all salamander species. More commonly, however, metamorphosis continues with the loss of gills, the growth (or increase in size) of legs, and the capability of the animal to function terrestrially.

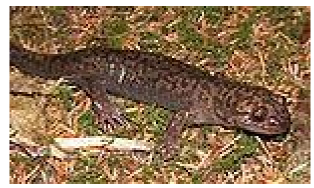
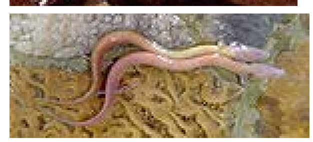
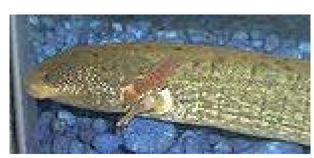
Declining populations

A general decline in living amphibian species, caused by the fungal disease chytridiomycosis, has had a significant effect on the salamander as well. While researchers have not yet found a direct link between the fungus and the population decline, they do believe it has played a role. Researchers also cite deforestation and climate change as possible contributing factors. This is based on surveys conducted in Guatemala during the 1970s as well as recently. Especially affected were Pseudoeurycea brunnata and Pseudoeurycea goebeli, both of which were abundant during the 1970s.

Taxonomy

There are ten families belonging to the order Caudata, divided into three suborders. The clade Neocaudata is often used to separate Cryptobranchoidea and Salamandroidea from the Sirenoidea.

Cryptobranchoidea (Giant salamanders)			
Family	**Common Names**	**Example Species**	**Example Photo**
Cryptobranchidae	Giant salamanders	Hellbender (*Cryptobranchus alleganiensis*)	
Hynobiidae	Asiatic salamanders	Hida Salamander (*Hynobius kimurae*)	
Salamandroidea (Advanced salamanders)			

Ambystomatidae	Mole salamanders	Marbled Salamander (*Ambystoma opacum*)	
Amphiumidae	Amphiumas or Congo eels	Two-toed Amphiuma (*Amphiuma means*)	
Dicamptodontidae	Pacific giant salamanders	Pacific Giant Salamander (*Dicamptodon tenebrosus*)	
Plethodontidae	Lungless salamanders	Red Back Salamander (*Plethodon cinereus*)	
Proteidae	Mudpuppies and olms	Olm (*Proteus anguinus*)	
Rhyacotritonidae	Torrent salamanders	Southern Torrent Salamander (*Rhyacotriton variegatus*)	
Salamandridae	Newts and true salamanders	Alpine Newt (*Triturus alpestris*)	
Sirenoidea (Sirens)			
Sirenidae	Sirens	Greater Siren (*Siren lacertina*)	

Chapter- 4

Caecilian (Type of Amphibian)

Caecilians **Temporal range: 170–0 Ma** **Lower Jurassic – Recent**	

Dermophis mexicanus

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	**Gymnophiona** Müller, 1832

Families

Rhinatrematidae
Ichthyophiidae
Uraeotyphlidae
Scolecomorphidae
Typhlonectidae

Caeciliidae

Distribution of caecilians (in green)

The **caecilians** are an order (**Gymnophiona**) of amphibians that superficially resemble earthworms or snakes. They mostly live hidden in the ground, which makes them one of the least known orders of amphibians. All extant caecilians and their closest fossil relatives are grouped as the clade Apoda.

Description

Caecilians completely lack limbs, making the smaller species resemble worms, while the larger species with lengths up to 1.5 m (4 ft 11 in) resemble snakes. The tail is short or absent, and the cloaca is near the end of the body.

Their skin is smooth and usually dark-matte, but some species have colorful skins. Inside the skin are calcite scales. Because of these scales, the caecilians were once thought to be related to the fossil Stegocephalia, but they are now believed to be a secondary development, and the two groups are most likely unrelated. The skin also has numerous ring-shaped folds, or annuli, that partially encircle the body, giving them a segmented appearance. Like other living amphibians, the skin contains glands that secrete a toxin to deter predators. The skin secretions of *Siphonops paulensis* have been shown to have hemolytic properties.

Caecilians' vision is limited to dark-light perception, and their anatomy is highly adapted for a burrowing lifestyle. They have a strong skull, with a pointed snout used to force their way through soil or mud. In most species, the number of bones in the skull are reduced and fused together, and the mouth is recessed under the head. Their muscles are adapted to pushing their way through the ground, with the skeleton and deep muscles acting as a piston inside the skin and outer muscles. This allows the animal to anchor its hind end in position, and force the head forwards, and then pull the rest of the body up to reach it in waves. In water or very loose mud, caecilians instead swim in an eel-like fashion. Caecilians in the family Typhlonectidae are aquatic as well as being the largest of their kind. The representatives of this family have a fleshy fin running along the rear section of their body, which enhances propulsion in water.

All but the most primitive caecilians have two sets of muscles for closing the jaw, compared with the single pair found in other creatures. These are more highly developed in the most efficient burrowers among the caecilians, and appear to help keep the skull and jaw rigid.

Adapting to their underground life, the eyes are small and covered by skin for protection, which has led to the misconception that they are blind. This is not strictly true, although their sight is limited to simple dark-light perception. All caecilians possess a pair of tentacles, located between their eyes and nostrils. These are probably used for a second olfactory capability, in addition to the normal sense of smell based in the nose.

Except for two lungless species — *Atretochoana eiselti* and *Caecilita iwokramae* — all caecilians have lungs, but also use the skin or the mouth for oxygen absorption. Often the left lung is much smaller than the right one, an adaptation to body shape that is also found in snakes.

Distribution

Caecilians are found in wet tropical regions of Southeast Asia, India and Sri Lanka, parts of East and West Africa, the Seychelles islands in the Indian Ocean and in northern and eastern South America. In Africa caecilians are found from Guinea-Bissau (*Geotrypetes*) to Southern Malawi (*Scolecomorphus*), with an unconfirmed record from eastern Zimbabwe. They have not been recorded from the extensive areas of tropical forest in central Africa. In South America they extend through subtropical eastern Brazil well into temperate northern Argentina. They can be seen as far south as Buenos Aires, when they are carried by the flood waters of the Parana River coming from farther north. The northernmost distribution is of the species *Ichthyophis sikkimensis* of Northern India. *Ichthyophis* is also found in South China and North Vietnam. In Southeast Asia, they do not cross Wallace's Line, and they are not found in Australia or the islands in between.

Reproduction

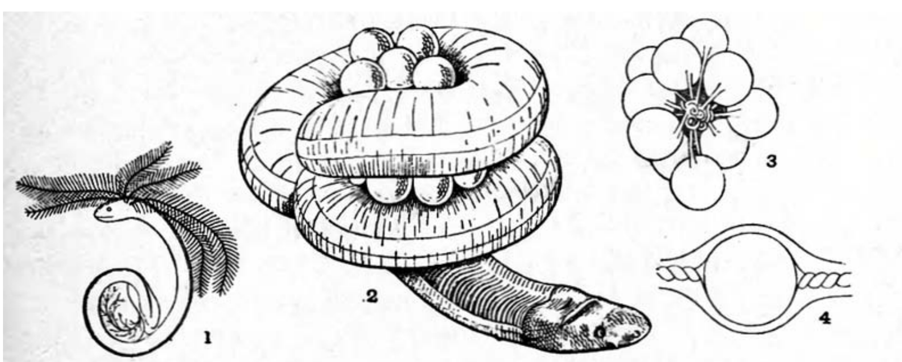


FIG. 15.—*Ichthyophis glutinosa* × 1. (After P. and F. Sarasin.) 1, A nearly ripe embryo, with gills, tail-fin, and still with a considerable amount of yolk ; 2, female guarding her eggs, coiled up in a hole underground ; 3, a bunch of newly laid eggs ; 4, a single egg, enlarged, schematised to show the twisted albuminous strings or chalazae within the outer membrane, which surrounds the white of the egg.

Maternal care in *Ichthyophis*

Caecilians are the only order of amphibians that use internal insemination exclusively (although the tailed frog in the U.S. does use a tail-like appendage for internal insemination in its fast flowing water environment). The male caecilians have a penis-like organ, the phallodeum, which is inserted into the cloaca of the female for 2 to 3 hours. About 25% of the species are oviparous (egg-laying); the eggs are guarded by the female. For some species the young caecilians are already metamorphosed when they hatch; others hatch as larvae. The larvae are not fully aquatic, but spend the daytime in the soil near the water.

75% of the species are viviparous, meaning that they give birth to already developed offspring. The fetus is fed inside the female with cells of the oviduct, which they eat with special scraping teeth.

The egg laying species *Boulengerula taitanus* feeds its young by developing an outer layer of skin, high in fat and other nutrients, which the young peel off with similar teeth. This allows them to grow by up to ten times their own weight in a week. The skin is consumed every three days, the time it takes for a new layer to grow, and the young have only been observed to eat it at night. It was formerly thought that the juveniles subsisted only on a liquid secretion from their mother.

Some larvae, such as those of *Typhlonectes*, are born with enormous external gills which are shed almost immediately. *Ichthyophis* is oviparous and known to show maternal care, with the mother guarding the eggs until they hatch.

Diet

The diet of caecilians is not well-known. Mature caecilians seem to feed mostly on insects and other invertebrates found in the habitat of the respective species. The stomach contents of 14 specimens of *Afrocaecilia taitana* consisted of mostly undefinable organic material and plant remains. Where identifiable remains were most abundant, they were found to be termite heads. While it was suggested that the undefinable organic material shows that the caecilians eat detritus, others believe these are in fact the remains of earthworms. Caecilians in captivity can be easily fed with earthworms, and worms are also common in the habitat of many caecilian species.

Etymology

The name *caecilian* derives from the Latin word *caecus*, meaning "blind", referring to the small or sometimes non-existent eyes. The name dates back to the taxonomic name of the first species described by Carolus Linnaeus, which he gave the name *Caecilia tentaculata*. The taxonomic name of the order derives from the Greek words γυμνος (*gymnos*, naked) and οφις (*ophis*, snake), as the caecilians were originally thought to be related to snakes.

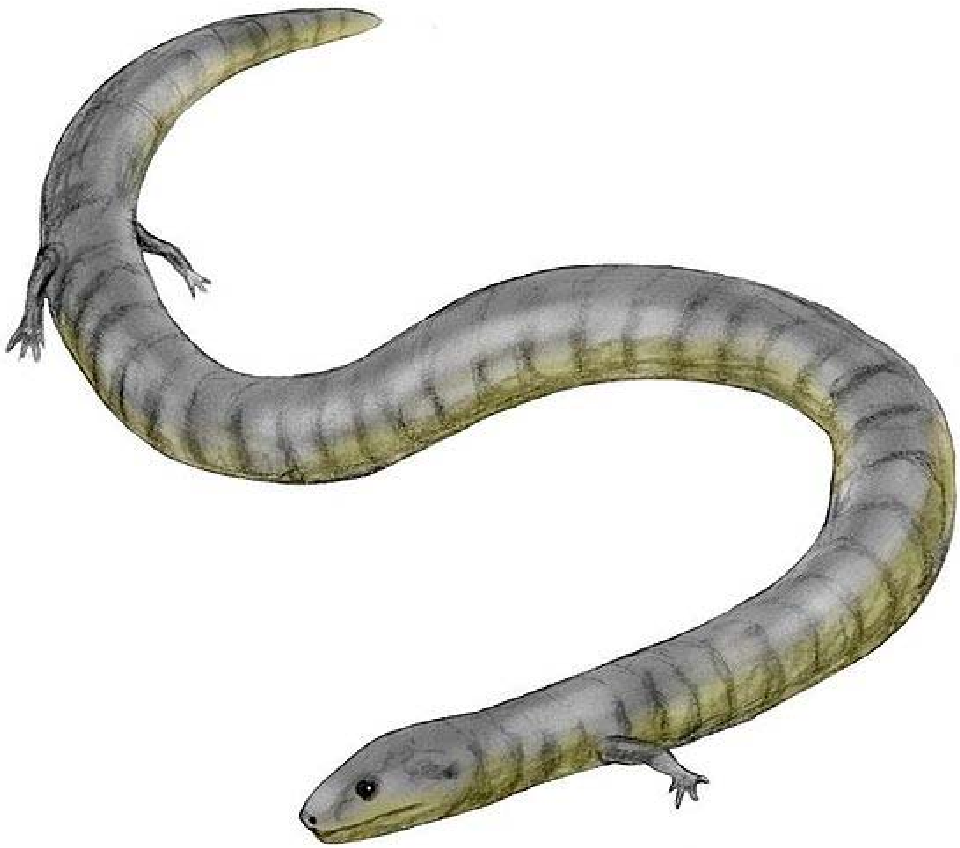
Taxonomy

Caecilian from the San Antonio Zoo

Until recently caecilians were divided into 6 families. In 2006 Daryl Frost of the American Museum of Natural History , along with 18 co-authors from around the world, published a major revision of amphibian classification. Based on parsimony analysis of DNA sequence data, Frost and co-authors found that some named groups of caecilians were nested within other such groups and should be subsumed into these, resulting in the current concept of three scientific families of caecilians. Although the taxonomic changes suggested in this work are somewhat controversial this controversy does not involve the changes to caecilian classification, which largely corroborated results from previous studies. Many described species are identified on the basis of a single specimen. It is almost certain that not all species have been described yet and also that some currently accepted species may be lumped together in future reclassifications.

- Beaked Caecilians (Rhinatrematidae) - 2 genera, 9 species, South America
- Fish Caecilians (Ichthyophiidae) - 3 genera, 44 species, Indo-Burma and Sundaland(including species formerly placed in Uraeotyphlidae)
- Common Caecilians (Caeciliidae) - 33 genera, 118 species, Africa, South America, Indo-Burma and Seychelles (including species formerly placed in Scolecomorphidae and Typhlonectidae)

Evolution



Eocaecilia, the earliest known caecilian

Little is known of the evolutionary history of the caecilians, which have left a sparse fossil record. The first fossil, a vertebra dated to the Paleocene, wasn't discovered until 1972. The earliest fossil known comes from the Jurassic period; its primitive genus, *Eocaecilia*, had small limbs and well-developed eyes. In their 2008 description of the fossil batrachian *Gerobatrachus* in 2008 Anderson and co-authors suggested that caecilians arose from the Lepospondyl group of ancestral tetrapods, and may be more closely related to amniotes than to frogs and salamanders, which arose from Temnospondyl ancestors. Divergent origins of caecilians and other living amphibians may help explain the discrepancy between fossil dates for the origins of modern amphibia, which suggest Permian origins, and the much earlier dates, in the Carboniferous, predicted by molecular clock studies of DNA sequences. Most morphological and molecular studies of living amphibians, however, support monophyly for caecilians, frogs and salamanders.

Chapter- 5

Amphibian Anatomy

Humeral spine

Male glassfrog, the bluish extension in the arm is the humeral spine

Humeral spines are ventrolateral extensions of the humeral crista ventralis. This structures are present in the humerus of some frogs (anurans). The majority of anuran species that present humeral spines are glassfrogs (family Centrolenidae) but humeral spines have been reported in various other species of different families of frogs, including Ceratophryidae and Hylidae. In all cases, humeral spines are present in males but not in females.

Tympanum (anatomy)

The **tympanum** is an external hearing structure in animals such as frogs, toads, insects, and mammals, to name a few.

Anurans

In frogs and toads, it is located just behind the eye. It does not actually process sound waves; it simply transmits them to the amphibian's inner ear, which is protected from water and other foreign objects.

Vocal sac

A fully distended vocal sac in an Australian Red-eyed Tree Frog (*Litoria chloris*)

The **vocal sac** is the flexible membrane of skin possessed by most male frogs. The purpose of the vocal sac is usually as an amplification of their mating or advertisement call. The presence or development of the vocal sac is one way of externally determining the sex of a frog in many species.

The vocal sac is open to the mouth cavity of the frog, with two slits on either side of the tongue. To call, the frog inflates its lungs. The air is then expelled from the lungs, through the larynx, and into the vocal sac. The vibrations of the larynx emits a sound, which resonates within the vocal sac. The resonance causes the sound to be amplified, and allows the call to carry further. Muscles within the body wall force the air back and forth between the lungs and vocal sac. The frogs mouth and nose are kept shut for the duration of the call.

Development

The development of the vocal sac is different in most species, however they mostly follow the same line. The development of the unilobular vocal sac begins with two small growths on the floor of the mouth. They begin to grow, until they form two small pouches. The pouches expand until they meet in the centre of the mouth, and form one large cavity, which grows until it is fully developed.

Purpose

The primary purpose of the vocal sac is to amplify the advertisement call of the male, and attract females from as large an area as possible. Species of frog without vocal sacs may only be heard within a radius of a few metres, whereas some species with vocal sacs can be heard over 1 km (0.62 mi) away. Modern frog species (Neobatrachians and some Mesobatrachians) which lack vocal sacs tend to inhabit areas close to flowing water. The sound of the flowing water overpowers the advertisement call, so they must advertise by other means.

An alternative use of the vocal sac, is that employed by the frogs of the Rhinodermatidae family. The males of the two species of this family will scoop recently hatched tadpoles into their mouth, where they will move into the vocal sac. The tadpoles of Darwin's Frog (*Rhinoderma darwinii*) will remain in the vocal sac until metamorphisis, whereas the Chile Darwin's Frog (*Rhinoderma rufum*) will transport the tadpoles to a water source.

Chapter- 6

Extinct Amphibians

Gastric-brooding frog

Gastric-brooding frogs/Platypus frogs

Southern Gastric-brooding Frog
(*Rheobatrachus silus*)

Conservation status

Extinct (IUCN 3.1)

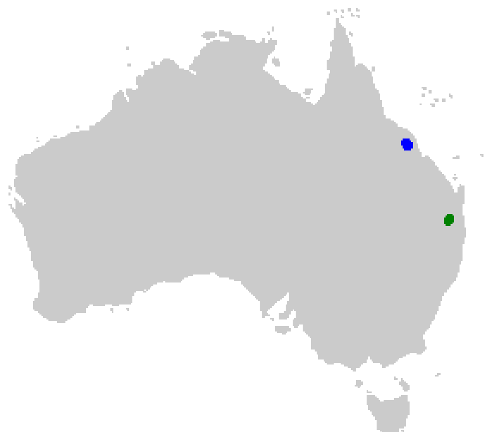
Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia

Order:	Anura
Suborder:	Neobatrachia
Family:	Myobatrachidae
Subfamily:	**Rheobatrachinae** Heyer and Liem, 1976
Genus:	***Rheobatrachus*** Liem, 1973

Species

Rheobatrachus silus
Liem, 1973
Rheobatrachus vitellinus
Mahony, Tyler, and Davies, 1984



The former distributions of *Rheobatrachus silus* (green) and *Rheobatrachus vitellinus* (blue).

The **gastric-brooding frogs** or **Platypus frogs** (*Rheobatrachus*) were a genus of ground-dwelling frogs native to Queensland in eastern Australia. The genus consisted of only two species, both of which became extinct in the mid-1980s. The genus was unique because it contained the only two known frog species that incubated the prejuvenile stages of their offspring in the stomach of the mother.

The combined ranges of the gastric-brooding frogs comprised less than 2000 km² (800 mi²). Both species were associated with creek systems in rainforests at elevations of between 350 metres (1,150 ft) and 1,400 metres (4,600 ft). The causes of the gastric-brooding frogs' extinction are not clearly understood, but habitat loss and degradation, pollution, and the amphibian chytrid fungus may have contributed.

The assignment of the genus to a taxonomic family is hotly debated. Some biologists class them within Myobatrachidae under the subfamily Rheobatrachinae, but others place them in their own family, Rheobatrachidae.

Taxonomy

Rheobatrachus was first described in 1973 by Liem and since has not undergone any scientific classification changes; however the placement of this genus within a family has been controversial. It has been placed in a distinct subfamily of Myobatrachidae, Rheobatrachinae, in a separate family, Rheobatrachidae, placed as the sister-taxon of Limnodynastinae and Rheobatrachinae has been synonymized with Limnodynastinae. Frost et al. (2006) found *Rheobatrachus*, on the basis of molecular evidence, the sister taxon of *Mixophyes* and placed it within Myobatrachidae.

Both species of gastric-brooding frogs were very different in appearance and behaviour to other Australian frog species. Their large protruding eyes and short, blunt snout along with complete webbing and slimy bodies differentiated them from all other Australian frogs. The largely aquatic behaviour exhibited by both species was only shared (in Australia) with the Dahl's Aquatic Frog and their ability to raise their young in the mother's stomach was unique among all frogs.

Common names

The common names, "Gastric-brooding frog" and "Platypus frog", are used to describe the two species. "Gastric-brooding" described the unique way the female raised the young and "platypus" describes their largely aquatic nature.

*Southern Gastric-brooding Frog (*R. silus*)*

Distribution

The Southern Gastric-brooding Frog (*Rheobatrachus silus*) was discovered in 1972 and described in 1973, however, there is one publication suggesting that the species was discovered in 1914 (from the Blackall Range). *Rheobatrachus silus* was restricted to the Blackall Range and Conondale Ranges in southeast Queensland, north of Brisbane, between elevations of 350 m and 800 m (1100 and 2600 feet) above sea level. The areas of rainforest, wet sclerophyll forest and riverine gallery open forest that it inhabited was limited to less than 1,400 km² (540 mi²). They were recorded in streams in the catchments of the Mary, Stanley and Mooloolah Rivers. Depending on the source, the last specimen seen in the wild was in 1979 in the Conondale Range, or in 1981 in the Blackall Ranges. The last captive specimen died in 1983. This species is believed to be extinct.

Physical description

The Southern Gastric-brooding Frog was a medium sized species of dull colouration, with large protruding eyes positioned close together and a short, blunt snout. Its skin was moist and coated with mucus. The fingers were long, slender, pointed and unwebbed and the toes were fully webbed. The arms and legs were large in comparison to the body. In both species the males were larger than the females.

The Southern Gastric-brooding Frog was a dull grey to slate coloured frog that had small patches, both darker and lighter than the background colouration, scattered over dorsal surface (back). The ventral surface was white or cream, occasionally with yellow blotches. The arms and legs had darker brown barring above and were yellow underneath. There was a dark stripe that ran from the eye to the base of the forelimb. The ventral surface (belly) was white with large patches of cream or pale yellow. The toes and fingers were light brown with pale brown flecking. The end of each digit had a small disc and the iris was dark brown. The skin was finely granular and the tympanum was hidden. The male Southern Gastric Brooding Frog was 33 millimetres (1.3 in) to 41 millimetres (1.6 in) in length and the female 44 millimetres (1.7 in) to 54 millimetres (2.1 in) in length.

Ecology and behaviour

The Southern Gastric-brooding Frog lived in areas of rainforest, wet sclerophyll forest and riverine gallery open forest. They were a predominately aquatic species closely associated with watercourses and adjacent rock pools and soaks. Streams that the Southern Gastric Brood Frog were found in were mostly permanent and only ceased to flow during years of very low rainfall. Sites where Southern Gastric-brooding Frogs were found usually consisted of closed forests with emergent eucalypts, however there was sites where open forest and grassy ground cover were the predominate vegetation. There is no record for this species occurring in cleared riparian habitat. Searches during spring and summer showed that the favored diurnal habitat was at the edge of rock pools, either amongst leaf litter, under or between stones or in rock crevices. They were also found under rocks in shallow water. Winter surveys of sites where Southern Gastric Brooding Frogs were common only recovered two specimens, and it is assumed that they hibernated during the colder months. Adult males preferred deeper pools than the juveniles and females which tended to inhabit shallower, newly created (after rain) pools that contained stones and/or leaf litter. Individuals only left themselves fully exposed while sitting on rocks during light rain.

The call of the Southern Gastric-brooding Frog has been described as an "eeeehm...eeeehm" with an upward inflection. It lasts for around 0.5 of a second and was repeated every 6-7 seconds.

Southern Gastric Brooding Frogs have been observed feeding on insects from the land and water. In aquarium situations Lepidoptera, Diptera and Neuroptera were eaten.

Being a largely aquatic species the Southern Gastric-brooding Frog was never recorded more than 4 m (13 ft) from water. Studies by Glen Ingram showed that the movements of this species were very restricted. Of ten juvenile frogs, only two moved more than 3 metres between observations. Ingram also recorded the distance moved along a stream by seven adult frogs between seasons (periods of increased activity, usually during summer). Four females moved between 1.8-46 m (6-151 ft) and three males covered 0.9-53 m (3-174 ft). Only three individuals moved more than 5.5 m (18 ft) (46 m, 46 m and 53 m). It appeared that throughout the breeding season adult frogs would remain in the same pools or cluster of pools, only moving out during periods of flooding or increased flow.

*Northern Gastric-brooding Frog (*R. vitellinus*)*

Distribution

The Northern Gastric-brooding Frog (*Rheobatrachus vitellinus*) was discovered and described in 1984. It was restricted to the rainforest areas of the Clarke Range in Eungella National Park in central eastern Queensland. This species, too, was confined to a small area — less than 500 km² (200 mi²), between 400 and 1000 metres (1000 and 3000 feet) in altitude. Only a year after its discovery, it was never seen again despite extensive efforts to locate it. This species is considered to be extinct.

Physical description

The Northern Gastric-brooding Frog was a much larger species than the Southern Gastric-brooding Frog. Males reached 50–53 mm (2.0–2.1 in) in length, and females 66–79 mm (2.6–3.1 in) in length. This species was also much darker in colour, usually pale brown, and like the Southern Gastric-brooding Frogs its skin was bumpy and had a slimy mucus coating. There were vivid yellow blotches on the abdomen and the underside of the arms and legs. The rest of the belly was white or grey in colour. The tympanum was hidden and the iris was dark brown. The body shape of the Northern Gastric Brooding Frog was very similar to the southern species.

Ecology and behaviour

The Northern Gastric-brooding Frog was only recorded in pristine rainforests where the only form of human disturbance was poorly defined walking tracks. As with the Southern Gastric-brooding Frog, the Northern Gastric-brooding Frog was also a largely aquatic species. They were found in and around the shallow sections of fast flowing creeks and streams where individuals were located in shallow, rocky, broken-water areas, in cascades, riffles and trickles. The water in these streams was cool and clear, and the frogs hid away beneath or between boulders in the current or in backwaters.

Male Northern Gastric-brooding Frogs call from the water's edge during summer. The call was loud, consisting of several staccato notes. It is similar to the Southern Gastric-brooding Frogs call although deeper, shorter and repeated less often.

The Northern Gastric-brooding Frog has been observed feeding on small crayfish, caddisfly larvae and terrestrial and aquatic beetles as well as the Eungella Torrent Frog (*Taudactylus eungellensis*).

Reproduction

What makes these frogs unique among all frog species is their form of parental care. Following external fertilization by the male, the female would take the eggs into her mouth and swallow them. It is not clear whether the eggs were laid on the land or in the water, as it was never observed prior to their extinction.

Eggs found in females measured up to 5.1 mm in diameter and had large yolk supplies. These large supplies are common among species that live entirely off yolk during their period of development. Most female frogs possessed around 40 ripe eggs. This number is almost double that of the number of juveniles ever to be observed occurring in the stomach (21-26). This means one of two things, that the female fails to swallow all the eggs or the first few eggs to be swallowed are digested.

At the time the female ingested the fertilized eggs her stomach was no different from that found in any other frog species. In the jelly that surrounded each egg was a substance called prostaglandin E_2 (PGE_2). This substance had the ability to turn off the production of hydrochloric acid in the stomach. This source of PGE_2 was enough to cease the production of acid during the embryonic stages of the developing eggs. Once the eggs had hatched the tadpoles too created PGE_2. The mucus excreted from the tadpoles gills contained the PGE_2 necessary to maintain the stomach in a non-functional state. These mucus excretions do not occur in tadpoles of most other species. Tadpoles that don't live entirely off a yolk supply still produce mucus cord, but the mucus along with small food particles travels down the oesophagus into the gut. With *Rheobatrachus* (and several other species) there is no opening to the gut and the mucus cords are excreted. During the period that the offspring were present in the stomach the frog would not eat.

Information on tadpole development was observed by a group that was regurgitated by the mother and successfully raised in shallow water. During the early stages of development tadpoles lacked pigmentation, but as they aged they progressively develop adult colouration. Tadpole development took at least six weeks, during this time the size of the mother’s stomach continued to increase until it largely filled the body cavity. The lungs deflated and breathing relied more upon gas exchange through the skin. Despite the mothers increasing size she still remained active.

The birth process was widely spaced and may have occurred over a period of as long as a week. However, if disturbed the female may regurgitate all the young frogs in a single act of propulsive vomiting. The offspring were completely developed when expelled and there was little variation in colour and length of a single clutch.

Cause of extinction

The cause for the gastric-brooding frogs' extinction is unknown but habitat loss/degradation, pollution, pathogens, parasites and over collecting may have contributed. A direct threat to the habitats through human activities was not clearly apparent and the amphibian chytrid fungus is suspected to have caused some if not most of the declines of these species.

Populations of Southern Gastric-brooding Frogs were present in logged catchments between 1972 and 1979. The effects of such logging activities upon Southern Gastric-brooding Frogs was not investigated but the species did continue to inhabit streams in the logged catchments. The habitat that the Southern Gastric-brooding Frog once inhabited is now threatened by feral pigs, the invasion of weeds, altered flow and water quality problems caused by upstream disturbances. Despite intensive searching, the species has not been located since 1979 or 1981 (depending on the source).

The Eungella National Park, where the Northern Gastric-brooding Frog was once found, was under threat from bushfires and weed invasion. Continual fires may have destroyed or fragmented sections of the forest. The outskirts of the park are still subject to weed invasion and the chytrid fungus has been located within several rainforest creeks within the park. It was thought that the declines of the Northern Gastric-brooding Frog during 1984 and 1985 were possibly normal population fluctuations. Despite continued efforts to locate the Northern Gastric-brooding Frog it has not been found. The last reported wild specimen was seen in the 1980s. In August 2010 a search organised by the Amphibian Specialist Group of the International Union for Conservation of Nature set out to look for various species of frogs thought to be extinct in the wild, including the gastric-brooding frog.

Conservation status

Both species are listed as *Extinct* under both the IUCN Red List and under Australia's Environment Protection and Biodiversity Conservation Act 1999; however, they are still listed as *Endangered* under Queensland's Nature Conservation Act 1992.

Golden toad

Golden Toad

Male golden toad

Conservation status

Extinct (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	Anura
Family:	Bufonidae
Genus:	*Bufo*
Species:	***B. periglenes***

Binomial name

Bufo periglenes
Savage, 1966

Synonyms

Cranopsis periglenes Frost et al., 2006
Ollotis periglenes Frost et al., 2006
Incilius periglenes Frost, 2008

The **golden toad** (***Bufo periglenes***) was a small, shiny, bright true toad that was once abundant in a small region of high-altitude cloud-covered tropical forests, about 30 square kilometers in area, above the city of Monteverde, Costa Rica. For this reason, it is sometimes also called the **Monteverde golden toad**, or the **Monte Verde toad**. Other common English names include **Alajuela toad** and **orange toad**. They were first described in 1966 by the herpetologist Jay Savage. Since May 15, 1989, not a single *B. periglenes* is reported to have been seen anywhere in the world, and it is classified by the IUCN as an extinct species. Its sudden extinction is cited as part of the decline in amphibian populations, which may be attributable to a fungal epidemic specific to amphibians or other factors, combined or acting independently.

Description

The golden toad was one of more than 500 species in the family Bufonidae — the "true toads". *B. periglenes* inhabited northern Costa Rica's Monteverde Cloud Forest Preserve, distributed over an area of roughly 10 square kilometres (3.9 sq mi) at an average elevation of 1.5 kilometres (0.93 mi).

Morphology

Adult males measured just barely 5 centimetres (2.0 in) long. Males have been described as being "Day-Glo golden orange", and unlike most toads their skin was shiny and bright. Jay Savage was so surprised upon first seeing them that he did not believe they could be real; he is quoted as saying: "I must confess that my initial response when I saw them was one of disbelief and suspicion that someone had dipped the examples in enamel paint." Exhibiting sexual dimorphism, female toads were slightly larger than the males, and looked very different. Instead of being bright orange, females were colored dark olive to black with scarlet spots encircled by yellow.

Reproduction

Very little is known about the behavior of *B. periglenes*; however, it is believed that they lived underground, as they were not seen for most of the year. In contrast, their presence in the Cloud Forest Preserve was obvious during their mating season, which lasted only a few weeks. For a few weeks in April, after the dry season ended and the forest became wetter, males would gather in large numbers near ground puddles and wait for the females. The males would fight with each other for opportunities to mate until the end of their short mating season, after which the toads retreated to their burrows. Eggs were laid in seasonal water catchments in clutches, the average size of which was 228 eggs. After two months, they hatched into tadpoles.

Males outnumbered females, in some years by as much as ten to one, a situation that often led bachelors to attack amplectant pairs and form what Savage once described as "writhing masses of toad balls." The eggs of the golden toad, black and tan spheres, were deposited in small pools--puddles--often no more than one inch deep. Tadpoles emerged in a matter of days, but required another four or five weeks for metamorphosis. During this period, they were highly dependent on the weather; too much rain and they would be washed down the steep hillsides, too little and their puddles would dry up. Golden toads were always found at an altitude of between forty-nine hundred and fifty-six hundred feet. In 1987, an American ecologist and herpetologist, Martha Crump, was fortunate enough to see the toad's mating rituals. In her book, *In Search of the Golden Frog* [*sic*], she described it as "one of the most incredible sights I've ever seen," and said they looked like "statues, dazzling jewels on the forest floor." On April 15, 1987, Crump recorded in her field diary that she counted 133 toads mating in one "kitchen sink-sized pool" that she was observing. Five days later, she witnessed the pools in the area drying, which she attributed to the effects of El Niño-Southern Oscillation, "leaving behind desiccated eggs already covered in mold." The toads attempted to mate again that May. Of the 43,500 eggs that Crump found, only twenty-nine tadpoles survived the drying of the forest's ground.

Conservation history

The Monteverde Cloud Forest Preserve, the golden toad's previous habitat.

Jay Savage first discovered the toads in 1966. From their discovery in 1966 for about 17 years, and from April to July in 1987, over 1500 adult toads were seen. Only ten or eleven toads were seen in 1988, including one seen by Crump, and none has been seen since May 15, 1989, when Crump last saw the same solitary male toad that she had seen the year before.

In the period between discovery and disappearance, the golden toad was commonly featured on posters promoting the biodiversity of Costa Rica. There is a single anecdotal report from the 1970s of a golden toad in the mountains of Guatemala near the village of

Chichicastenango, but this sighting has not been confirmed. There is also another extinct frog sometimes compared to the golden toad found in the same forest in Costa Rica, named Holdridge's Toad.

Extinction

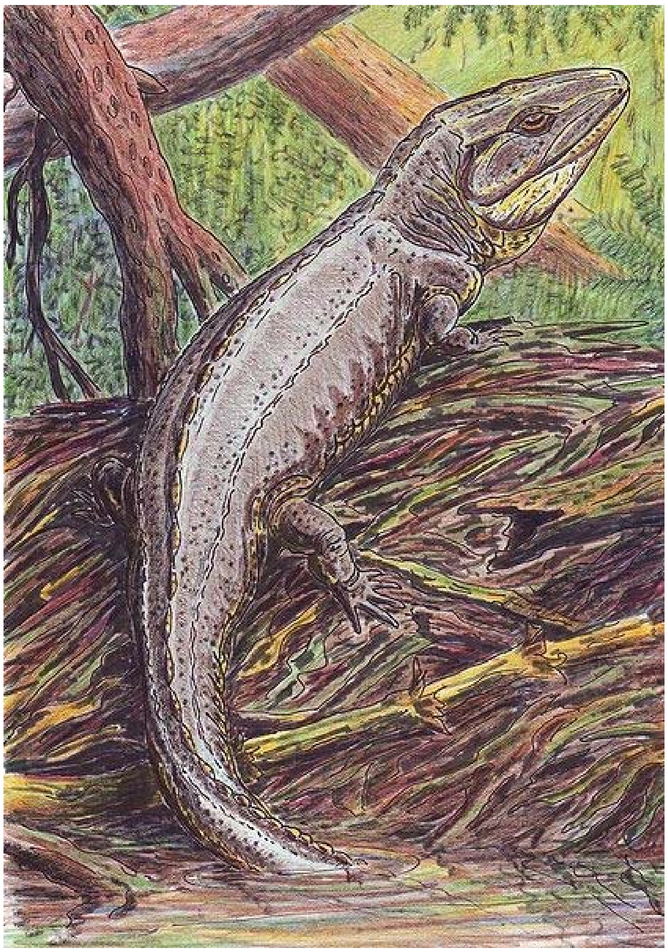
In the spring of 1987, an American biologist who had come to the cloud forest specifically to study the toads counted fifteen hundred of them in temporary breeding pools. That spring was unusually warm and dry and most of the pools evaporated before the tadpoles in them had time to mature. The following year, only one male was seen at what previously had been the major breeding site. Seven males and two females were seen at a second site a few miles away. The year after, only one male was found.. No golden toad has been seen since then. As late as 1994, five years after the last sighting, researchers still hoped that *B. periglenes* continued to live in underground burrows, as similar toad species have lifespans of up to twelve years. By 2004 IUCN listed the species as extinct, after an evaluation involving Savage (who had first discovered them 38 years earlier). IUCN's extinction was based on the lack of sightings since 1989 and the "extensive search[ing]" that had been done since without result. In August 2010 a search organised by the Amphibian Specialist Group of the International Union for Conservation of Nature set out to look for various species of frogs thought to be extinct in the wild, including the golden toad.

Jennifer Neville has examined the different hypotheses explaining the extinction of the golden toad in her article "The Case of the Golden Toad: Weather Patterns Lead to Decline". Neville comes to the conclusion that Crump's El Niño hypothesis is "clearly support[ed]" by the available data. IUCN gives numerous possible reasons in its description of the past threats to the species, including "[the golden toad's] restricted range, global warming, chytridiomycosis and airborne pollution". Neville also mentions arguments that an increase in UV-B radiation, fungus or parasites, or lowered pH levels contributed to the Golden Toad's extirpation.

A more recent study confirms the El Niño hypothesis, in which it is stated that "The new study finds that Monteverde was the driest it’s been in a hundred years following the 1986-1987 El Niño, but that those dry conditions were still within the range of normal climate variability". The new study has shown that the Chytrid Fungus has spread due to the dry conditions caused by El Niño.

Labyrinthodontia

Labyrinthodontia Fossil range: 395–100 Ma Descendant taxon Amniotes and Lissamphibians survives to present.



Proterogyrinus, an anthracosaur.

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Amphibia *sensu lato*
Subclass:	**Labyrinthodontia** Owen, 1860

Included groups

- Order **Ichthyostegalia** †
- Order **Temnospondyli** † (possible ancestors of

modern amphibians)

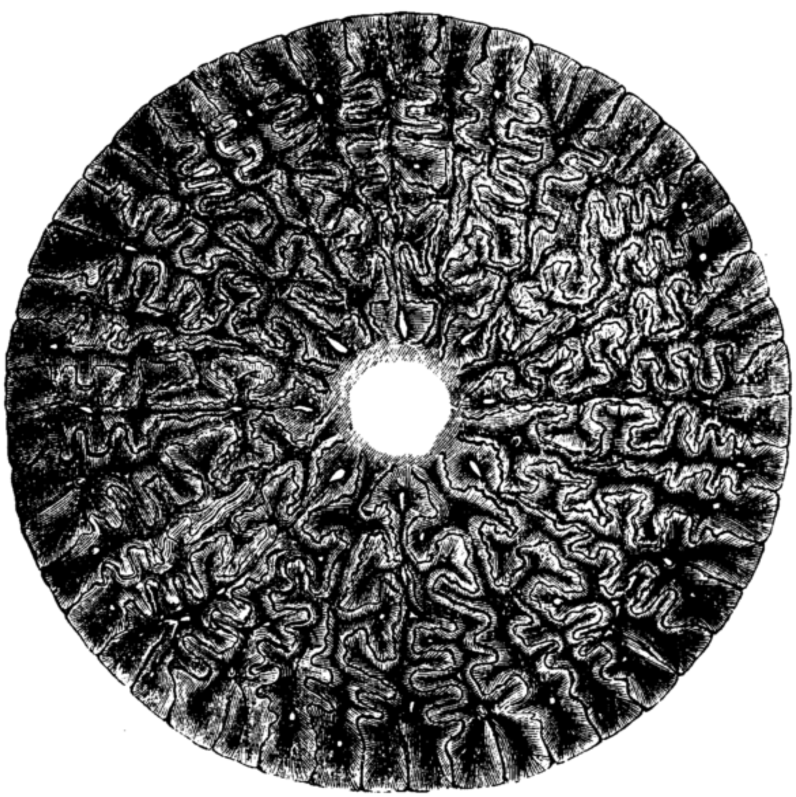
- Subclass **Lepospondyli** † (possible ancestors of modern amphibians)
- Order **Reptiliomorpha** † (ancestors of reptiles)

Excluded groups

- Lissamphibians
- Amniotes

Labyrinthodontia (Greek, "maze-toothed") is an older term for any member of the extinct subclass of amphibians, which constituted some of the dominant animals of Late Paleozoic and Early Mesozoic times (about 390 to 210 million years ago). The group is ancestral to all extant landliving vertebrates, and as such constitute an evolutionary grade (a paraphyletic group) rather than a clade. The name describes the pattern of infolding of the dentin and enamel of the teeth, which are often the only part of the creatures that fossilize. They are also distinguished by a heavily armoured skull roof (hence the older name "Stegocephalia"), and complex vertebrae, the structure of which is useful in older classifications of the group.

Labyrinthodont traits

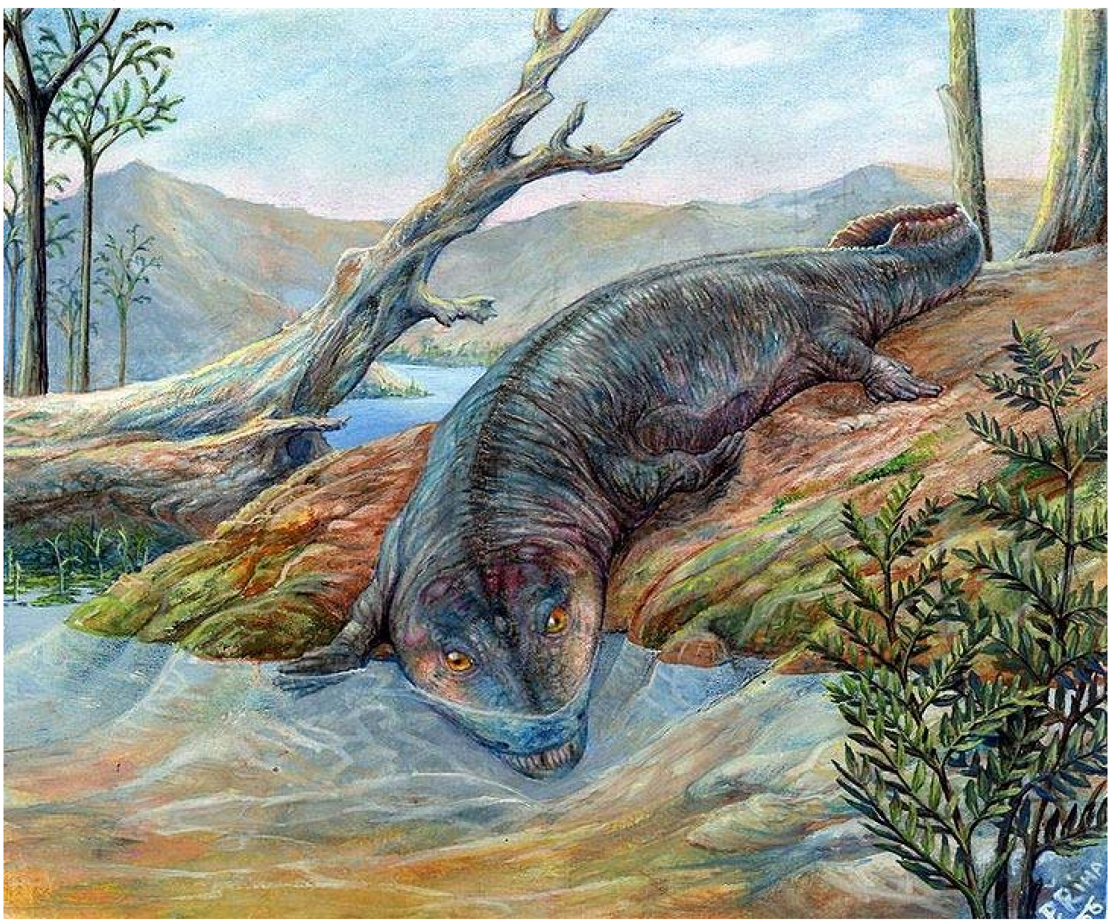


Cross-section of a labyrinthodont tooth

The labyrinthodonts flourished for more than 200 million years. Particularly the early forms exhibited a lot of variation, yet there are still a few basic anatomical traits that make their fossils very distinct and easily recogniseable in the field:

- **Strongly folded tooth surface**, involving infolding of the dentin and enamel of the teeth, so that a cross section resembles a classical labyrinth (or maze), hence the name of the group.
- **Massive skull roof**, with openings only for the nostrils, eyes and a parietal eye, similar to the structure of the anapsids. With the exception of the later more reptile-like forms, the skull was rather flat with copious dermal armour, accounting for the older term for the group: *Stegocephalia*.
- **Otic notch** behind each eye at the back edge of the skull. In the primitive waterbound forms it may have formed an open spiracle, and may possibly have held a tympanic membrane in some advanced forms.
- **Complex vertebrae** made of 4 pieces, an intercentrum, two pleurocentra, and a vertebral arch/spine. The relative sizes and ossification of the elements is highly variable.

The labyrinthodonts in life

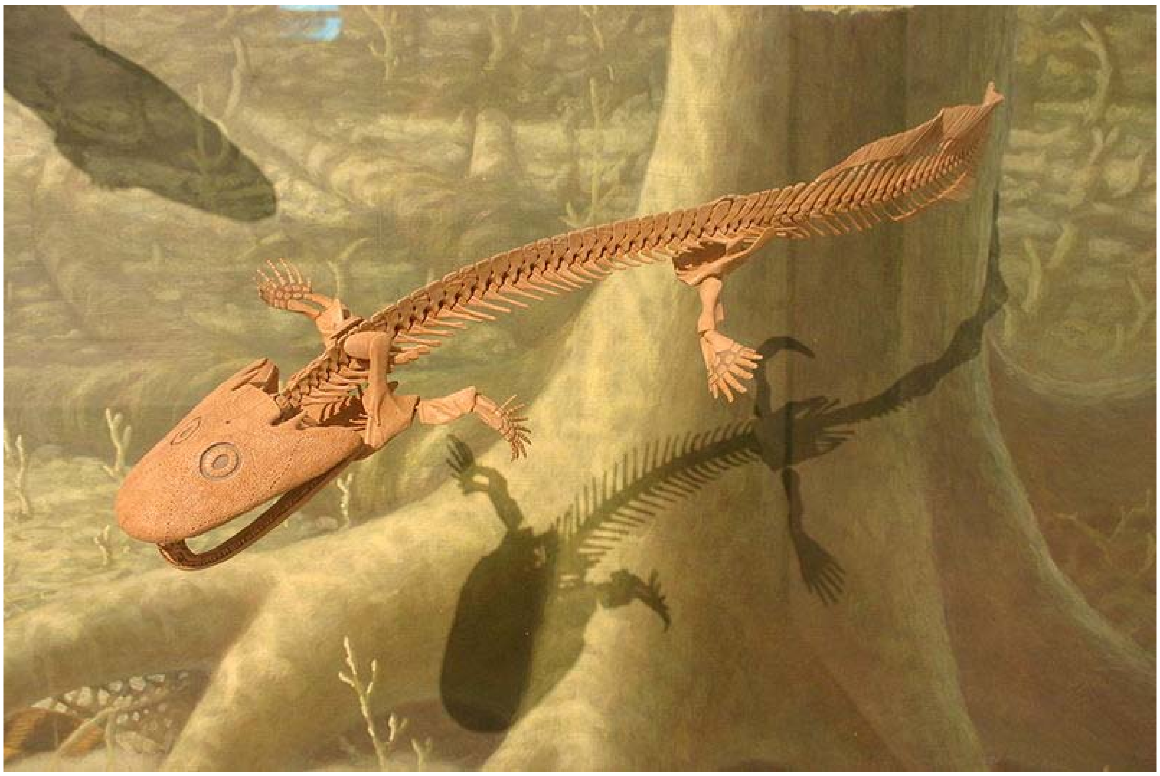


Early (ichthyostegalian) labyrinthodont.

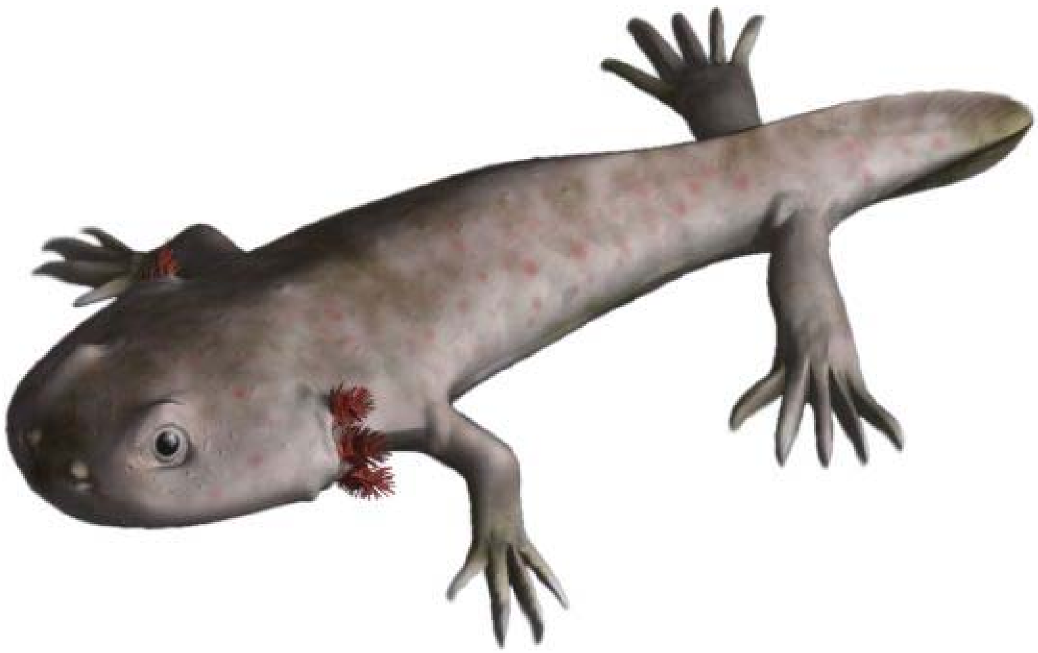
General build

Labyrinthodonts were generally amphibian-like in build. They were short-legged and mostly large headed, with moderately short to long tails. Many groups, and all the early forms, were large animals. Primitive members of all labyrinthodont groups were probably true water predators, and various degrees of amphibious, semi-aquatic and semi terrestrial modes of living arose independently in different groups. Some lineages remained or became secondarily fully aquatic with reduced limbs and elongated, eel-like bodies.

Skeleton



Skeletal reconstruction of *Acanthostega*, an early (ichthyostegalian) labyrinthodont.



Reconstruction of *Branchiosaurus*, a temnospondyl tadpole or paedomorph form with external gills.

With the exception of the snake-like aïstopods, the skulls of labyrinthodonts were massive. Their jaws were lined with small, sharp, conical teeth and had a second row of larger teeth on the roof of the mouth. All teeth were labyrinthodont. The sole exception were the chisel-like teeth of some of the advanced herbivorous diadectomorphs. The skull had prominent otic notches behind each eye and a parietal eye.

The complex labyrinthodont vertebrae and short, broad leg bones indicate most labyrinthodonts would have been slow and clumsy on land. Some of the larger adults may have been confined to water. Some late Paleozoic groups, particularly microsaurs and seymouriamorphs, were small to medium-sized and would have been competent terrestrial animals. Some of the advanced diadectomorphs from the Late Carboniferous and Early Permian were fully terrestrial with stout skeletons, and were the heaviest land animals of their time. The Mesozoic labyrinthodonts were mostly aquatic with increasingly cartilaginous skeleton.

Sensory apparatus

The eyes of most labyrinthodonts were situated at the top of the skull, offering good vision upwards, but very little lateral vision. The parietal eye was prominent, although there is uncertainty as to whether it was a true image producing organ or one that could only register light and dark, like that of the modern tuatara.

Like modern fish, most labyrinthodonts had special sense organs in the skin, forming a lateral line organ for perception of water flow and pressure. This would enable them to pick up the vibration of their prey and other water-born sounds while hunting in murky, weed filled waters. Early labyrinthodont groups had massive stapes, likely primarily anchoring the brain case to the skull roof. It is a question of some doubt whether early terrestrial labyrinthodonts had the stapes connected to a tympanum covering their otic notch, and if they had an aerial sense of hearing at all. The tympanum in modern amphibians and amniotes appear to have evolved separately, indicating most, if not all, Labyrinthodonts were unable to pick up airborne sound.

Respiration

The early labyrinthodonts possessed well developed internal gills as well as primitive lungs, derived from the swim bladders of their ancestors. They could breathe air, which would have been a great advantage for residents of warm shoals with low oxygen levels in the water. There was no diaphragma; air was inflated into the lungs by contractions of a special throat sac. Many aquatic forms retained their larval gills in adulthood.

Reproduction

The labyrinthodonts were amphibious—they laid eggs in the water, where their tadpoles matured and eventually ventured onto land on occasion. Fossil tadpoles from several species are known, as well as neotenic adults with feathery external gills similar to those found in modern lissamphibian tadpoles and in fry of lungfish and bichirs. The existence of a larval stage as the primitive condition in all groups of labyrinthodonts can be fairly safely assumed, in that tadpoles of *Discosauriscus*, a close relative of the amniotes, are known.

Groups of labyrinthodonts

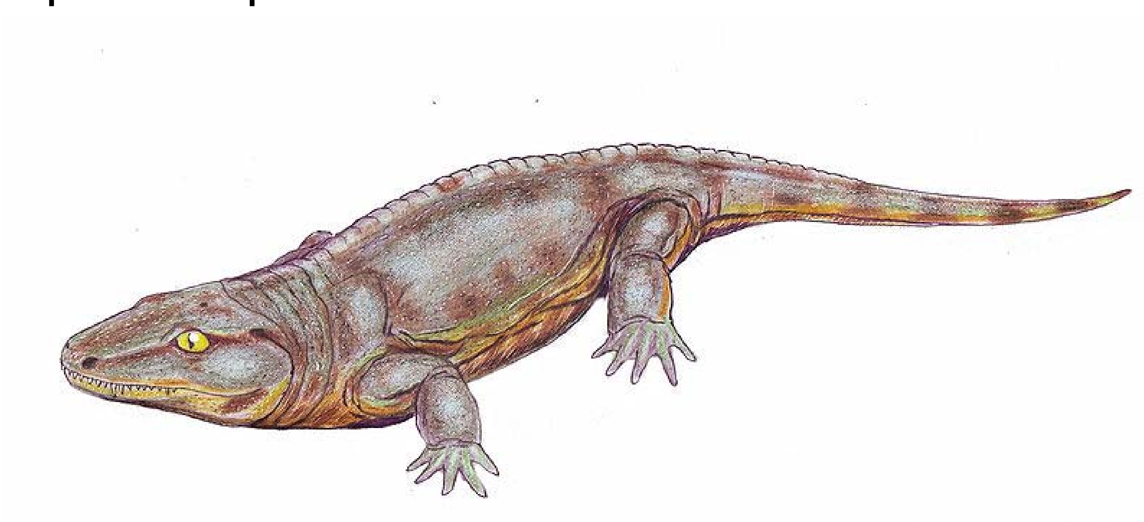
The systematic placement of groups within Labyrinthodontia is notoriously fickle. Several groups are identified, but there is no consensus of their phylogenetic relationship. Many key groups were small with moderately ossified skeletons, and there is a gap (the "Romer's gap") in the fossil record in the early Carboniferous when most of the groups formed. Further complicating the picture is the amphibian larval-adult life cycle, with physical changes throughout life complicating phylogenetic analysis. The Labyrinthodontia appear to be composed of several nested clades. The two best understood groups, the Ichthyostegalia and the reptile-like amphibians have from the outset been known to be paraphyletic. Tellingly, labyrinthodont systematics was the subject of the inaugural meeting of International Society for Phylogenetic Nomenclature.

Ichthyostegalia

Acanthostega, a fish-like early ichthyostegalian.

The early labyrinthodonts are known from the Devonian and possibly extending into the Romer's Gap of the early Carboniferous. These labyrinthodonts are often grouped together as the order Ichthyostegalia, though the group is an evolutionary grade rather than a clade. Ichthyostegalians were predominately aquatic and most show evidence of functional internal gills throughout life, and probably only occasionally ventured onto land. Their polydactylous feet had more than the usual five digits for tetrapods and were paddle-like. The tail bore true fin rays like those found in fish. The vertebrae were complex and rather weak. At the close of the Devonian, forms with progressively stronger legs and vertebrae evolved, and the later groups lacked functional gills as adults. All were however predominately aquatic and some spent all or nearly all their lives in water.

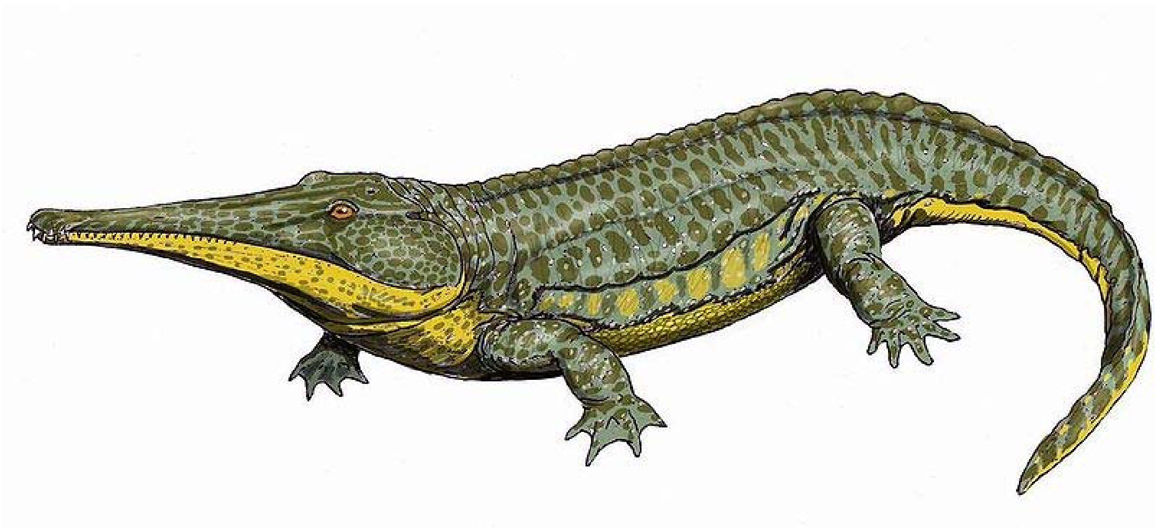
Reptile-like amphibians



Seymouria, a terrestrial reptiliomorph from the Permian.

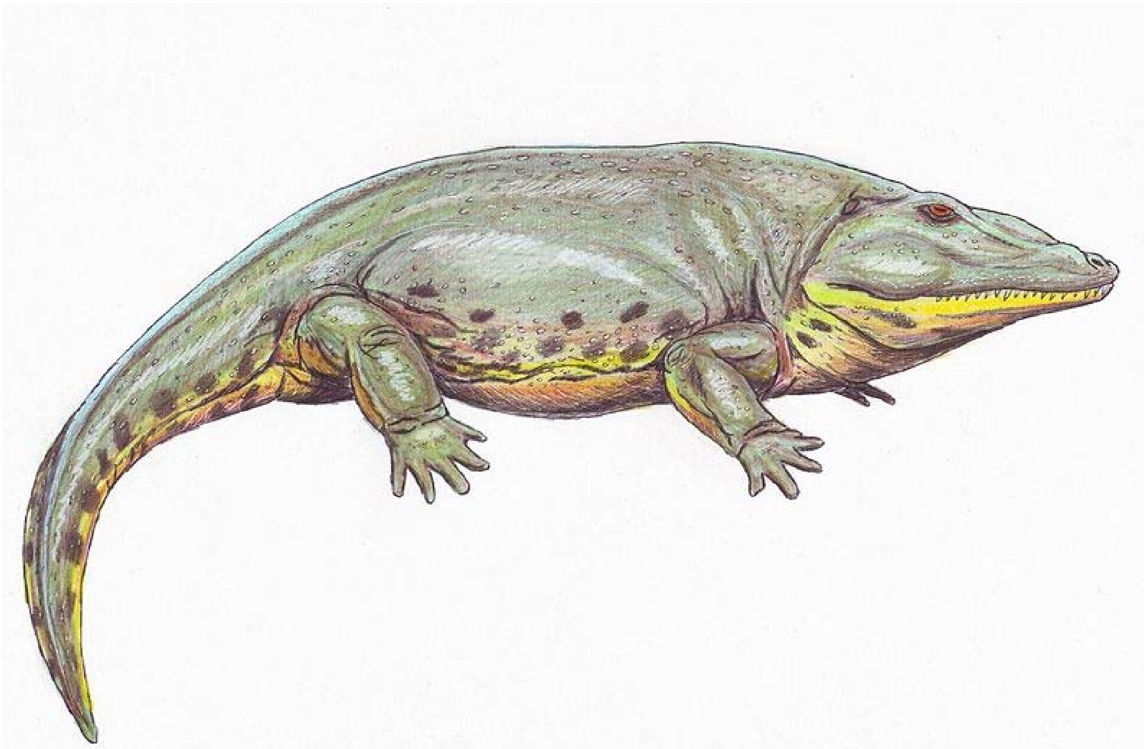
An early branch was the terrestrial reptile-like amphibians, variously called Anthracosauria or Reptiliomorpha. With the exception of aquatic Embolomeri and the diadectomorphs, they were moderately sized creatures that appeared in the early Carboniferous. Their skulls were relatively deep and narrow compared to other labyrinthodonts. Front and hind feet bore five digits on most forms. The vertebrae of the group foreshadowed that of primitive reptiles, with small pleurocentra, which grew and fused to become the true centrum in later vertebrates. The most well known genus is *Seymouria*. Some members of the most advanced group, the Diadectomorpha, were herbivorous and grew to several meters in length, with great, barrel-shaped bodies. Small relatives of the diadectomorphs gave rise to the first reptiles in the Late Carboniferous.

Temnospondyli



Platyoposaurus, an advanced crocodile-like temnospondyl from the Permian.

The most diverse group of labyrinthodonts was the Temnospondyli. Temnospondyls appeared the Late Devonian and came in all sizes, from small salamander-like Stereospondyli that scurried along the waters edge and undergrowth, to giant, well armoured Archegosauroidea that looked more like crocodiles. The largest member of family Archegosauridae, *Prionosuchus*, is estimated to have been up to 9 meters long, the largest amphibian ever known to have lived.



Eryops, a well known euskelian temnospondyl.

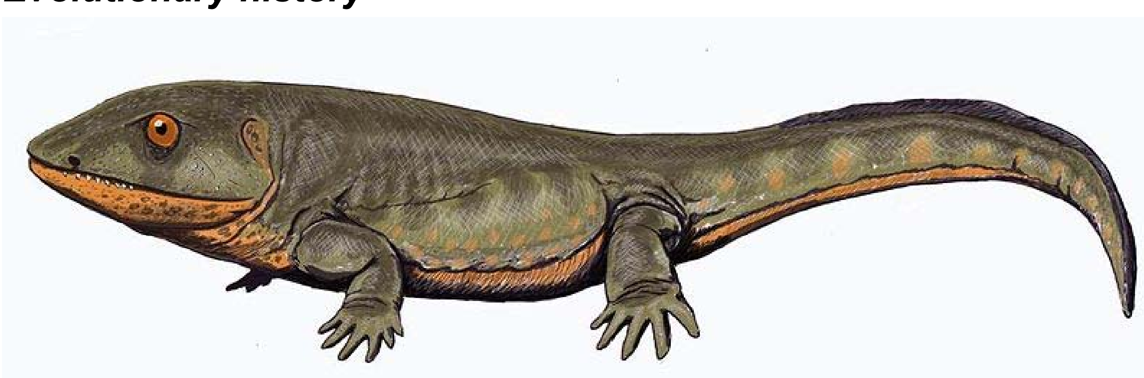
A temnospondyl's fore-foot had only four toes, and the hind-foot five, similar to the pattern seen in modern amphibians. Temnospondyls had a conservative vertebral column in which the pleurocentra remained small in primitive forms, vanishing entirely in the more advanced ones. The intercentra bore the weight of the animal, being large and forming a complete ring. All were more or less flat-headed with either strong or secondarily weak vertebrae and limbs. There were also fully aquatic forms, like the Dvinosauria, and even marine forms such as the Trematosauridae. The Temnospondyli may have given rise to the modern frogs and salamanders in the late Permian or early Triassic.

Lepospondyli

Hyloplesion, a salamander-like lepospondyl.

A small group of uncertain origin, the Lepospondyli evolved mostly small species that can be found in European and North American Carboniferous and early Permian strata. They are characterized by simple spool-shaped vertebrae formed from a single element, rather than the complex system found in other labyrinthodont groups. Most were aquatic and external gills are sometimes found preserved. The Leposondyli were generally salamander-like, but one group, the Aïstopoda, was snakelike with flexible, reduced skulls. Some microsaur lepospondyls were squat and short-tailed and appear to have been well adapted to terrestrial life. The best known genus is *Diplocaulus*, a nectridean with a boomerang-shaped head. The position of Lepospondyli in relation to other labyrinthodont groups is uncertain, and it is sometimes classified as a separate subclass. There is some doubt as to whether the lepospondyls form a phylogenetic unit at all, or is a wastebasket taxon containing the paedamorphic forms and tadpoles of other labyrinthodonts, notably the reptiliomorphs.

Evolutionary history



Pederpes, a six-fingered Labyrinthodont from the fossil-poor Romer's gap.

Tiktaalik, a transitional form between tetrapodomorph fish and labyrinthodonts, combining fishlike fins with a pectoral girdle separate from the skull

The Labyrintodonts have their origin in the early middle Devonian or possibly earlier. They evolved from a bony fish group: the fleshy-finned Rhipidistia. The only other living group of Rhipidistans alive today are the lungfish, the sister group of the landliving vertebrates. Earliest traces of the land-living forms are fossil trackways from Zachełmie quarry, Poland, dated to 395 million years ago, attributed to an animal with feet very similar to Ichthyostega.

Swamp predators

By the late Devonian, land plants had stabilized freshwater habitats, allowing the first wetland ecosystems to develop, with increasingly complex food webs that afforded new opportunities. The early labyrinthodonts were mostly aquatic, hunting in shallow water along tidal shores or weed filled tidal channels. From their piscine ancestors, they had inherited swim bladders that opened to the oesophagus and were capable of functioning as lungs (a condition still found in lungfish and some primitive ray-finned fishes). They were all carnivorous, initially eating fish and possibly going ashore to feed off washed up carrion, only later turning into predators of the large invertebrates of the Devonian at the waters edge. Early fossil tetrapods have been found in marine sediments, suggesting marine and brackish areas were their primary habitat. This is further corroborated by fossils of early labyrinthodonts being found scattered all around the world, indicating they must have spread by following the coastal lines rather than through freshwater only.

The first labyrinthodonts were all large to moderately large animals, and would have suffered considerable problems on land. While they retained gills and fish-like skulls and tails with fin rays, the early forms can readily be separated from Rhipidistan fish by the cleithrum/scapula complex being separate from the skull to form a pectoral girdle and carry the weight of the front end of the animals. The various early forms are for convenience grouped together as Ichthyostegalia.

While the bode shape and proportions went largely unchanged throughout their evolutionary history, the limbs of the Ichthyostegalians underwent a rapid evolution. The proto-Labyrinthodonts like from *Elginerpeton* and *Tiktaalik* had fin-like feet with no clear fingers, primarily suited for movement in water, but also capable of propelling the animal across sandbanks and through vegetation filled waterways. *Ichthyostega* and *Acanthostega* had paddle-like polydactyl feet with stout bony toes that also enabled them to walk on land. The semi-aquatic Ichthyostegalians flourished in tidal channels and swampland through the remainder of the Devonian, only to disappear from the fossil record at the transition to the Carboniferous.

Onto land

The end of the Devonian saw the late Devonian extinction event, followed by a gap in the fossil record of some 15 million years at the start of the Carboniferous, called the "Romer's gap. The gap marks the disappearance of the Ichthyostegalian forms as well as the origin of the higher Labyrinthodonts. Finds from this period found in East Kirkton Quarry includes the peculiar, probably secondarily aquatic *Crassigyrinus*, which may represent the sister group group later Labyrinthodont groups.

Early Carboniferous saw the radiation of the family Loxommatidae, a mysterious group that may have been the ancestors or sister taxon of the higher groups. While most Labyrinthodonts remained aquatic or semi-aquatic, a small group called reptile-like amphibians adapted to explore the terrestrial niches as small or medium sized predators. They evolved increasingly terrestrial adaptions during the Carboniferous, including stronger vertebrae and slender limbs, and a deeper skull with laterally placed eyes. They probably had watertight skin, possibly covered in horny scutes. To the modern eye, these animals would appear like heavyset reptiles, only betraying their amphibious nature when spawning aquatic eggs. In the middle or late Carboniferous, smaller forms gave rise to the first reptiles. In the late Carboniferous, the reptilomorph family Diadectidae evolved herbivory, becoming the largest terrestrial animals of the day with barrel-shaped, heavy bodies. There were also a family of corresponding carnivores, the Limnoscelidae, that flourished briefly in the late Carboniferous.

Heyday of the Labyrinthodonts

The waterways of coal forests, the typical primal hunting grounds of Carboniferous Labyrinthodonts

The herbivorious Diadectidae reached their maximum diversity in the late Carboniferous/early Permian, and then quickly declined, their role taken over by early reptilian herbivores like Pareiasaurs and Edaphosaurs. Unlike the reptile-like amphibians, the Temnospondyli remained more or less aquatic, feeding on fish and perhaps other Labyrinthodonts. They underwent a major diversification in the late Carboniferous and early Permian, thriving in the swamps and coal forests in continental shallow basins around equatorial Pangaea and around the Paleo-Tethys Ocean.

Several adaptions to piscivory evolved with some groups having crocodile-like skulls with slender snouts, and presumably had a similar life-style (Archegosauridae, Melosauridae, Cochleosauridae and Eryopidae, and the reptile-like suborder Embolomeri). Others, evolved as aquatic ambush predators, with short, broad skulls that allowed for opening the mouth by tipping the skull back rather than dropping the jaw (Plagiosauridae and the divinosaur families). In life they would have hunted rather like the modern day monkfish, and several groups are known to have retained the larval gills into adulthood, being fully aquatic. A third form adapted to hunting in shallows and murky swamps, with ∩-shaped skull, much like their Devonian ancestors (Metoposauridae).

In Euramerica, the Lepospondyli, a host of small, mostly aquatic amphibians of uncertain phylogeny, appeared in the Carboniferous. They lived as denizens of the undergrowth and small ponds, much like modern amphibians. In the Permian, the peculiar Nectridea found their way to Gondwanaland.

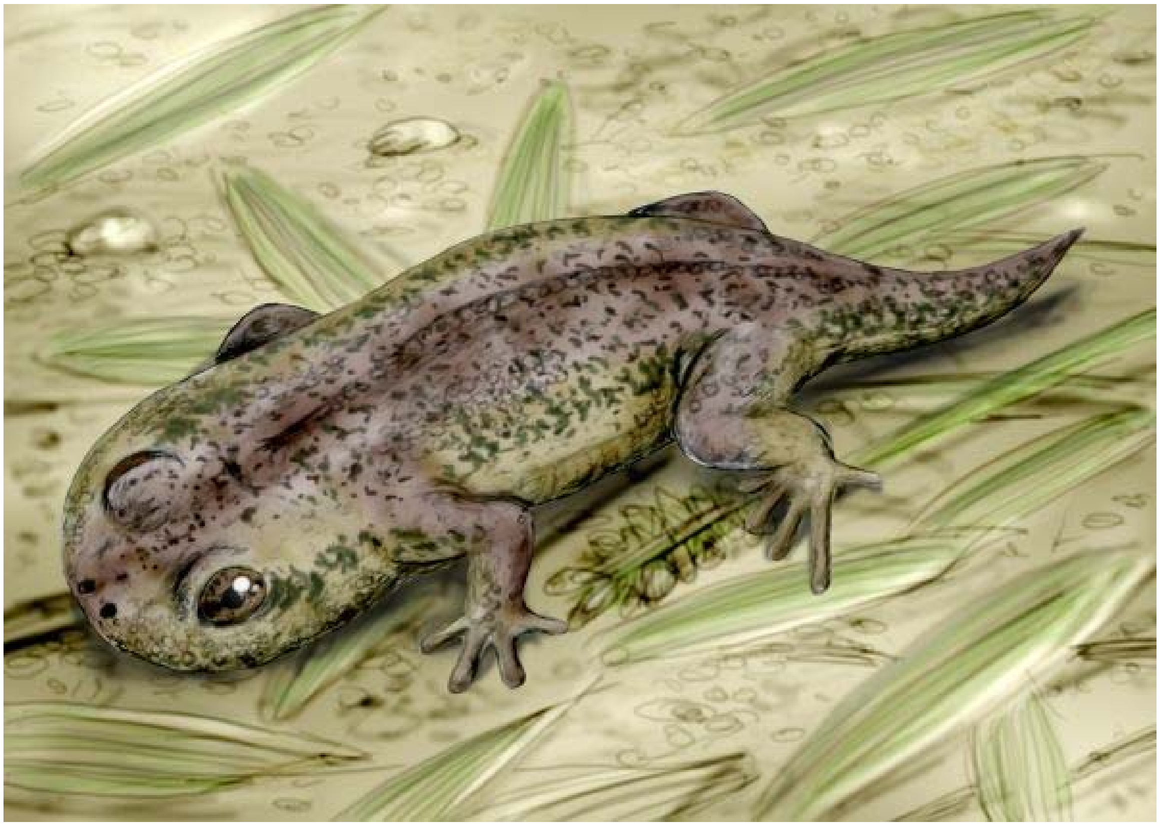
Decline

From the middle of the Permian, the climate dried up, making life difficult for the amphibians. The terrestrial Reptiliomorphs disappeared, though aquatic crocodile-like Embolomeri continued to thrive until going extinct in the Triassic. The diverse Lepospondyl inhabitants of the undergrowth disappear from the fossil record, among them the snake-like Aïstopoda.

With the close of the Palaeozoic, most of the Permian groups disappeared, with the exception of the Mastodonsauroid and Metoposaurid families and the curious Plagiosauridae, who continued into the Triassic. Life in the waterways of continental shallows saw several large forms from these families, like *Thoosuchus*, *Benthosuchus* and *Eryosuchus*. Their ecological niches were probably similar to those of modern day crocodiles, as fish hunters and riverside carnivores. All groups developed progressively weaker vertebrae, reduced limb ossification and flatter skulls with prominent lateral line organs, indicating the late Permian/early Triassic Temnospondyls rarely if ever left the water. An extremely large Brachyopid (likely a plagiosaur or a close relative) is estimated to have been 7 meters long, and probably just as heavy as the Permian *Prionosuchus*.

With the rise of the real crocodiles in the middle Triassic, even these Temnospondyli went into decline, though some hung on to at least early Cretaceous on the southern Gondwanaland, in regions too cold for crocodiles.

Origin of modern amphibians



The amphibamid temnospondyl *Gerobatrachus* from the Permian, proposed ancestor of lissamphibians

There is today a general consensus that all modern amphibians, the Lissamphibia, have their origin in Labyrinthodont stock, but this is where consensus ends. The fragile bones of the Lissamphibians are extremely rare as fossils, and the modern amphibians are highly derived, making comparison with fossil Labyrinthodonts difficult.

Traditionally, the Lepospondyli has been favored as lissamphibian ancestors. Like the modern amphibians, they were mostly small with simple vertebrae, resembling lissamphibians in many aspects of external anatomy and presumably ecological niches. At a subclass level, it was thought that labyrinthodonts gave rise to leopspondyls, and lepospondyls to lissamphibians. Several cladistic studies also favour the lepospondyl link, though placing Lepospondyli as close relatives or even derived from reptile-like amphibians. One problem with this position is the question of whether Lepospondily actually is monophyletic in the first place.

Temnospondyl affinity for the Lissamphibia is suggested by other works. The temnospondyl family Amphibamidae has been considered a possible candidate for the ancestors of lissamphibians. The amphibamid *Gerobatrachus*, described in 2008, was proposed to be a transitional form between temnospondyls and anuras (frogs and toads) and caudatans (salamanders). It possessed a mixture of anuran and caudatan features, including a broad skull, short tail, and small pedicellate teeth.

Complicating the picture is the question of whether Lissamphibia itself may be polyphyletic. Though a minority view, several variants have been forwarded through history. The "Stockholm school" under Gunnar Säve-Söderbergh and Erik Jarvik argued that Amphibia as a whole is biphyletic, based on details of the nasal capsul and cranial nerves. In their view lepospondyls are ancestors of frogs, while salamanders and caecilians have evolved independently from porolopiform fish. Robert L. Carroll suggested the tailed amphibians (salamanders and caecilians) are derived from lepospondyl microsaurs and frogs from temnospondyls. The cladistic analysis of *Gerobatrachus* suggests salamanders and frogs have evolved from temnospondyl stock and caecilians being the sister group of the reptile-like amphibians, rendering Lissamphibia itself an evolutinary grade relative to the remaining tetrapod classes. A consensus on origin of lissamphibians and relationship between the various labyrinthodonts is not likely to materialise soon.

Classification

Classical 19th century interpretation of Stegocephalians from the Crystal Palace, based on anuran amphibians.

The term *Labyrinthodont* was coined by Hermann Burmeister in reference to the tooth structure. Labyrinthodontia was first used as a systematic term by Richard Owen in 1860, and assigned to Amphibia the following year. It was ranked as an order under class

Amphibia by Watson in 1920 and as a superorder by Romer in 1947. An alternative name, *Stegocephalia* was created in 1868 by American palaentologist Edward Drinker Cope, from Greek *stego cephalia*—"roofed head", and refer to the copious amounts of dermal armour some of the larger forms evidently had. This term is widely used in 19th and early 20th century literature.

The earliest finds was attempted classified on the basis of skull roof, often the only part of part of the specimen preserved. With the frequent convergent evolution of head shape in Labyrinthodonts, this led to form taxa only. The relationship of the various groups to each other and to the Lissamphibians (and to some degree the first reptiles) is still a matter of some debate. Several schemes have been forwarded, and at present there is no consensus among workers in the field.

Vertebral classification

A systematic approach based on the relative size and shape of the elements of the complex Labyrinthodont vertebrae was favored in the early 20th century. This classification quickly fell into disuse as some forms of backbones appear to have appeared more than once and different types are found in close relatives, sometimes even in the same animal! The classification presented here is from Case, 1946:

- Order **Stegocephalia** (= Labyrinthodontia)
    - "Grade" **Rachitomi** (Primitive complex vertebrae, all Ichthyostegalia, most large Temnospondyli and some Reptiliomorpha)
    - "Grade" **Embolomeri** (Intercentrum and pleurocentrum cylinders if equal size, today considered a suborder of secondarily aquatic Reptiliomorpha)
    - "Grade" **Stereospondyli** (Simplified backbones with only intercentrum and vertebral arch, still recognized as a valid group)
- Order **Phyllospondyli** (Small, flimsy vertebrae, today considered to represent tadpoles and paedomorphic forms)
- Order **Lepospondyli** (Spool-shaped or cylindrical vertebrae, mid Carboniferous to mid Permian, phylogeny uncertain)
- Order **Adelospondyli** (Cylindrical vertebrae with conical depressions at each end meeting in the middle, now considered a Lepospondyl group)
- Order **Gymnophiona** (extant)
- Order **Urodela** (extant)
- Order **Anura** (extant)

Traditional classification

The traditional classification was initiated by Säve-Söderbergh in the 1930s. He believed that Amphibia was biphyletic, and that salamanders and caecilians had evolved independently from porolopiform fish. Few shared Säve-Söderbergh's view of a biphyletic Amphibia, but his scheme, either with the Lepospondyli as a separate subclass or sunk into Temnospondyli, was continued by Romer 1966 and followed by several subsequent authors (Colbert 1969, Daly 1973, Carroll 1988 and Hildebrand & Goslow 2001): The classification cited here is from Romer & Parson, 1985:

- Subclass **Labyrinthodontia**
    - Order **Ichthyostegalia** (primitive ancestral forms (e.g. *Ichthyostega*)—Middle to late Devonian only).
    - Order **Temnospondyli** (Late Devonian to Cretaceous, e.g. *Eryops*, possibly ancestral to modern amphibians)
    - Order **Anthracosauria** (Carboniferous and Permian, e.g. *Seymouria*, ancestral to early reptiles)
- Subclass **Lepospondyli** (Carboniferous and Permian, e.g. *Diplocaulus*, small group, possibly ancestral to modern amphibians)
- Subclass **Lissamphibia** (Permian to present)
    - Order **Gymnophiona** (extant)
    - Order **Urodela** (extant)
    - Order **Anura** (extant)

Benton's classification

Benton's influential Vertebrate Palaeontology has a more detailed scheme, dividing the amphibians into a series of unassigned families, corresponding to Ichthyostegalia in the classical scheme and splitting the Lepospondyli and reptile-like Labyrinthodonts up into separate orders. The orders are grouped into subclasses Batrachomorpha and Reptiliomorpha, representing the orders thought more closely related to modern amphibians and reptiles respectively:

- A number of unassigned primitive families, corresponding to "Ichtyostegalia" †
- Subclass Batrachomorpha
    - Order **Temnospondyli** †
    - Order **Aïstopoda** †
    - Order **Nectridea** †
    - Order **Microsauria** †
    - Order **Gymnophiona** (extant)
    - Order **Urodela** (extant)
    - Order **Anura** (extant)
- Subclass Reptiliomorpha (corresponding to Anthracosauria in the classical scheme)
    - Order **Anthracosauria** †
    - Order **Seymouriamorpha** †
    - Order **Diadectomorpha** †
    - Amniotes

The name Labyrinthodontia in cladistics

While Labyrinthodontia is a traditional designation and a name commonly found in textbooks, the name has fallen out of favor in recent taxonomies as paraphyletic: the group does not include all the descendants of their most recent common ancestor. Various groups that have traditionally been placed within Labyrinthodontia are currently variously classified as stem tetrapods, basal tetrapods, non-amniote Reptiliomorpha and as a monophyletic or paraphyletic Temnospondyli, according to cladistic analysis. This reflects the emphasis of ascertaining lineage and ancestral-descendant relatedness in modern-day cladistics. The name does however linger as a handy reference for the early amphibian tetrapods, and as an apt anatomical description of their distinct tooth pattern.

A cladistic term with somewhat similar, though uncertain meaning is Stem Tetrapoda, a stem group. The actual content of the latter is a matter of some uncertainty, as the phylogenetic tree, which the stem group concept is based on, is not well understood.

Chapter- 7

Decline in Amphibian Populations

The Golden toad of Monteverde, Costa Rica, was among the first casualties of amphibian declines. Formerly abundant, it was last seen in 1989.

Dramatic **declines in amphibian populations**, including population crashes and mass localized extinctions, have been noted since the 1980s from locations all over the world. These declines are perceived as one of the most critical threats to global biodiversity, and several causes are believed to be involved, including disease, habitat destruction and modification, exploitation, pollution, pesticide use, introduced species, climate change, and increased ultraviolet-B radiation (UV-B). However, many of the causes of amphibian declines are still poorly understood, and the topic is currently a subject of much ongoing research. Calculations based on extinction rates suggest that the current extinction rate of amphibians could be 211 times the background extinction rate and the estimate goes up to 25,039–45,474 times if endangered species are also included in the computation.

Background

In the past three decades, declines in populations of amphibians (the group of organisms that includes frogs, toads, salamanders, newts, and caecilians) have occurred worldwide. In 2004, the results were published of the first worldwide assessment of amphibian populations, the Global Amphibian Assessment. This found that 32% of species were globally threatened, at least 43% were experiencing some form of population decrease, and that between 9 and 122 species have become extinct since 1980. As of 2010, the IUCN Red List, which incorporates the Global Amphibian Assessment and subsequent updates, lists 486 amphibian species as "Critically Endangered".

Declines have been particularly intense in the western United States, Central America, South America, eastern Australia and Fiji (although cases of amphibian extinctions have appeared worldwide). While human activities are causing a loss of much of the world's biodiversity, amphibians appear to be suffering much greater effects than other species of organisms. Because amphibians generally have a two-staged life cycle consisting of both aquatic (larvae) and terrestrial (adult) phases, they are sensitive to both terrestrial and aquatic environmental effects. Because their skins are highly permeable, they may be more susceptible to toxins in the environment than other organisms such as birds or mammals. Many scientists believe that amphibians serve as "canaries in a coal mine," and that declines in amphibian populations and species indicate that other groups of animals and plants will soon be at risk.

Declines in amphibian populations were first widely recognized in the late 1980s, when a large gathering of herpetologists reported noticing declines in populations in amphibians across the globe. Among these species, the Golden toad of Monteverde, Costa Rica featured prominently. The Golden Toad, *Bufo periglenes*, was the subject of scientific investigation until populations suddenly crashed in 1987 and disappeared completely by 1989. Other species at Monteverde, including the Monteverde Harlequin Frog (*Atelopus varius*), also disappeared at the same time. Because these species were located in the pristine Monteverde Cloud Forest Reserve, and these extinctions could not be related to local human activities, they raised particular concern among biologists.

Initial skepticism

When amphibian declines were first presented as a conservation issue in the late 1980s, some scientists remained unconvinced of the reality and gravity of the conservation issue. Some biologists argued that populations of most organisms, amphibians included, naturally vary through time. They argued that the lack of long-term data on amphibian populations made it difficult to determine whether the anecdotal declines reported by biologists were worth the (often limited) time and money of conservation efforts.

However, since this initial skepticism, biologists have come to a consensus that declines in amphibian populations are a real and severe threat to biodiversity. This consensus emerged with an increase in the number of studies that monitored amphibian populations, direct observation of mass mortality in pristine sites that lacked apparent cause, and an awareness that declines in amphibian populations are truly global in nature.

Potential causes

Numerous potential explanations for amphibian declines have been proposed. Most or all of these causes have been associated with some population declines, so each cause is likely to affect in certain circumstances but not others. Many of the causes of amphibian declines are well-understood, and appear to affect other groups of organisms as well as amphibians. These causes include habitat modification and fragmentation, introduced predators or competitors, introduced species, pollution, pesticide use, or over-harvesting. However, many amphibian declines or extinctions have occurred in pristine habitats where the above effects are not likely to occur. The causes of these declines are complex, but many can be attributed to emerging diseases, climate change, increased ultraviolet-B radiation, or long-distance transmission of chemical contaminants by wind.

Artificial lighting has been suggested as another potential cause. Insects are attracted to lights making them scarcer within the amphibian habitats.

Habitat modification

Habitat modification or destruction is one of the most dramatic issues affecting amphibian species worldwide. As amphibians generally need aquatic and terrestrial habitats to survive, threats to either habitat can affect populations. Hence, amphibians may be more vulnerable to habitat modification than organisms that only require one habitat type. Large scale climate changes may further be modifying aquatic habitats, preventing amphibians from spawning altogether.

Killer Fungus

Amphibians like frogs and toads have existed for 360 million years and survived when dinosaurs did not, but a new aquatic fungus is threatening to make many of them extinct, according to an article in the November issue of Microbiology Today. The fungus, *Batrachochytrium dendrobatidis* (Bd), was found to be associated with waves of amphibian extinctions in Central America and north-eastern Australia in the 1990s. Bd infects over 350 amphibian species by penetrating their skin, but little else is known about where it came from and how it causes disease.

The earliest published record of Bd is from a specimen of an African clawed frog in 1938 from South Africa. Around this time there was a huge trade in clawed frogs when they were used in one of the earliest human pregnancy tests. The global exportation of the clawed frog is likely to have spread Bd around the world. The infection is spread by fungal spores released into the water supply from imported infected animals.

Researchers are trying different approaches to treat existing Bd infection. Some are treating tadpoles with antifungal drugs, whilst more innovative approaches involve introducing 'probiotic' bacteria that naturally secrete antifungal compounds which kill Bd on amphibians' skin. To help limit the spread of infection, the World Organization for Animal Health now recommends screening imported amphibians for presence of Bd.

Habitat fragmentation

Habitat fragmentation occurs when habitats are isolated by habitat modification, such as when a small area of forest is completely surrounded by agricultural fields. Small populations that survive within such fragments are often susceptible to inbreeding, genetic drift, or extinction due to small fluctuations in the environment.

Pollution and chemical contaminants

There is evidence of chemical pollutants causing frog developmental deformities (extra limbs, or malformed eyes). Pollutants have varying effects on frogs. Some alter the central nervous system; others like atrazine cause a disruption in the production and secretion of hormones. Experimental studies have also shown that exposure to commonly used herbicides such as glyphosate (Tradename Roundup) or insecticides such as malathion or carbaryl greatly increase mortality of tadpoles. Additional studies have indicated that terrestrial adult stages of amphibians are also susceptible to non-active ingredients in Roundup, particularly POEA, which is a surfactant. Atrazine has been shown to cause male tadpoles of African clawed frogs to become hermaphroditic with development of both male and female organs. Such feminization has been reported in many parts of the world. In a study conducted in a laboratory at Uppsala University in Sweden, more than 50% of frogs exposed to levels of estrogen-like pollutants existing in natural bodies of water in Europe and the United States became females. Tadpoles exposed even to the weakest concentration of estrogen were twice as likely to become females while almost all of the control group given the heaviest dose became female.

While most pesticide effects are likely to be local and restricted to areas near agriculture, there is evidence from the Sierra Nevada mountains of the western United States that pesticides are traveling long distances into pristine areas, including Yosemite National Park in California.

Some recent evidence points to ozone as a possible contributing factor to the worldwide decline of amphibians.

Ozone depletion, ultraviolet radiation and cloud cover

Like many other organisms, increasing ultraviolet-B (UVB) radiation due to stratospheric ozone depletion and other factors may harm the DNA of amphibians, particularly their eggs. The amount of damage depends upon the life stage, the species type and other environmental parameters. Salamanders and frogs that produce less photolyase, an enzyme that counteracts DNA damage from UVB, are more susceptible to the effects of loss of the ozone layer. Exposure to ultraviolet radiation may not kill a particular species or life stage but may cause sublethal damage.

More than three dozen species of amphibians have been studied with severe effects reported in more than 40 publications in peer-reviewed journals representing authors from North America, Europe and Australia. Experimental enclosure approaches to determine UVB effects on egg stages have been criticized, for example, egg masses were placed at water depths much shallower than is typical for natural oviposition sites. While UVB radiation is an important stressor for amphibians, its effect on the egg stage may have been overstated.

Anthropogenic climate change has likely exerted a major effect on amphibian declines. For example, in the Monteverde Cloud Forest, a series of unusually warm years led to the mass disappearances of the Monteverde Harlequin frog and the Golden Toad. An increased level of cloud cover, which has warmed the nights and cooled down daytime temperatures in an attempt to control global warming, has been blamed for facilitating the growth and proliferation of the fungus *Batrachochytrium dendrobatidis* (the causative agent of the fungal infection chytridiomycosis).

Although the immediate cause of the die offs was the chytrid, climate change played a pivotal role in the extinctions. Researchers included this subtle connection in their inclusive climate-linked epidemic hypothesis, which acknowledged climatic change as a key factor in amphibian extinctions both in Costa Rica and elsewhere.

New evidence has shown global warming to also be capable of directly degrading toads' body condition and survivorship. Additionally, the phenomenon often colludes with landscape alteration, pollution, and species invasions to effect amphibian extinctions.

Disease

A number of diseases have been related to mass die-offs or declines in populations of amphibians, including "red-leg" disease (*Aeromonas hydrophila*), *Ranavirus* (family Iridoviridae), *Anuraperkinsus*, and chytridiomycosis. It is not entirely clear why these diseases have suddenly begun to affect amphibian populations, but some evidence suggests that these diseases may have been spread by humans, or may be more virulent when combined with other environmental factors.

Trematodes

There is considerable evidence that parasitic trematode platyhelminths (a type of fluke) have contributed to developmental abnormalities and population declines of amphibians in some regions. These trematodes of the genus *Ribeiroia* have a complex life cycle with three host species. The first host includes a number of species of aquatic snails. The early larval stages of the trematodes then are transmitted into aquatic tadpoles, where the metacercariae (larvae) encyst in developing limb buds. These encysted life stages produce developmental abnormalities in post-metamorphic frogs, including additional or missing limbs. These abnormalities increase frog predation by aquatic birds, the final host of the trematode.

A deformed mink frog with one extra leg

A study showed that high levels of nutrients used in farming and ranching activities fuel parasite infections that have caused frog deformities in ponds and lakes across North America. The study showed increased levels of nitrogen and phosphorus cause sharp hikes in the abundance of trematodes, and that the parasites subsequently form cysts in the developing limbs of tadpoles causing missing limbs, extra limbs and other severe malformations including five or six extra or even no limbs.

Chytridiomycosis

A chytrid-infected frog.

In 1998, following large-scale frog deaths in Australia and Central America, research teams in both areas came up with identical results: a previously undescribed species of pathogenic fungus, *Batrachochytrium dendrobatidis*. It is now clear that many recent extinctions of amphibians in Australia and the Americas are linked to this fungus. This fungus belongs to a family of saprobes known as chytrids that are not generally pathogenic.

The disease caused by *Batrachochytrium dendrobatidis* is called chytridiomycosis. Frogs infected by this disease generally show skin lesions and hyperkeratosis, and it is believed that death occurs because of interference with skin functions including maintenance of fluid balance, electrolyte homeostasis, respiration and role as a barrier to infections. The time from infection to death has been found to be 1–2 weeks in experimental tests, but infected animals can carry the fungus as long as 220 days. There are several hypotheses on the transmission and vectors of the fungus.

Subsequent research has established that the fungus has been present in Australia since at least 1978, and present in North America since at least the 1970s. The first known record of chytrid infection in frogs is in the African Clawed Frog, *Xenopus laevis*. Because *Xenopus* are sold in pet stores and used in laboratories around the world, it is possible that the chytrid fungus may have been exported from Africa.

Introduced predators

Non-native predators and competitors have also been found to affect the viability of frogs in their habitats. The mountain yellow-legged frog which typically inhabits the Sierra Nevada lakes have seen a decline in numbers due to stocking of non-native fish (trout) for recreational fishing. The developing tadpoles and froglets fall prey to the fish in large numbers. This interference in the frog's three year metamorphosis is causing a decline that is manifest throughout their ecosystem.

Increased noise levels

Frogs and toads are highly vocal, and their reproductive behaviour often involves the use of vocalizations. There have been suggestions that increased noise levels caused by human activities may be contributing to their declines. In a study in Thailand, increased ambient noise levels were shown to decrease calling in some species and to cause an increase in others. This has, however, not been shown to be a cause for the widespread decline.

Symptoms of stressed amphibian populations

Amphibian populations in the beginning stages of decline often exude a number of signs, which may potentially be used to identify at-risk segments in conservation efforts. One such sign is developmental instability, which has been proven as evidence of environmental stress. This environmental stress can potentially raise susceptibility to diseases such as chytridiomycosis, and thus lead to amphibian declines. In a study conducted in Queensland, Australia, for example, populations of two amphibian species, *Litoria nannotis* and *Litoria genimaculata*, were found to exhibit far greater levels of limb asymmetry in pre-decline years than in control years, the latter of which preceded die offs by an average of 16 years. Learning to identify such signals in the critical period before population declines occur might greatly improve conservation efforts.

Conservation measures

On 16 February 2007, scientists worldwide met in Atlanta, Georgia to form a group called the Amphibian Ark to help save more than 6,000 species of amphibians from disappearing by starting captive breeding programs. Conservation efforts have been created by several organizations such as Amphibian Conservation Alliance (ACA) and the World Wildlife Fund to help further studies on frog extinction and educate people on the issue at hand. Areas with noticed frog extinctions, like Australia, have few policies that have been created to prevent the extinction of these species. However, local initiatives have been placed where conscious efforts to decrease global warming will also turn into a conscious effort towards saving the frogs. In South America where there is also and increased decline of amphibian populations, there is no set policy to try to save frogs. Some suggestions would include getting entire governments to place a set of rules and institutions as a source of guidelines that local governments have to abide by.

Chapter- 8

Amphibians of Africa

African clawed frog

African clawed frog

Conservation status

Least Concern (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	Anura

Family:	Pipidae
Genus:	*Xenopus*
Species:	***X. laevis***

Binomial name

Xenopus laevis
Daudin, 1802

The **African clawed frog** (*Xenopus laevis*, also known as the **platanna**) is a species of South African aquatic frog of the genus *Xenopus*. Its name is derived from the three short claws on each hind foot, which it uses to tear apart its food. The word *Xenopus* means "strange foot" and *laevis* means "smooth".

African clawed frogs can grow up to a length of 5 in (12 cm). They have a flattened head and body, but no tongue or external ears.

The species is found throughout most of Africa, and in isolated, introduced populations in North America, South America, and Europe. All species of the *Pipidae* family are tongueless, toothless and completely aquatic. They use their hands to shove food in their mouths and down their throats and a hyobranchial pump to draw or suck food in their mouth. Pipidae have powerful legs for swimming and lunging after food. They also use the claws on their feet to tear pieces of large food. They lack true ears but have lateral lines running down the length of the body and underside, which is how they can sense movements and vibrations in the water. They use their sensitive fingers, sense of smell, and lateral line system to find food. *Pipidae* are scavengers and will eat almost anything living, dying or dead and any type of organic waste.

There are 14 species of *Xenopus* with *Xenopus gilli* being the most endangered.

Description

These frogs are plentiful in ponds and rivers within the south-eastern portion of Sub-Saharan Africa. They are aquatic and are often greenish-grey in color. Albino varieties are commonly sold as pets. “Wild-type” African Clawed Frogs are also frequently sold as pets, and often incorrectly labeled as a Congo Frog or African Dwarf Frog because of similar colorings. They are easily distinguished from African Dwarf Frogs because African Clawed Frogs have webbing only on their hind feet while African Dwarf Frogs have webbing on all four feet. They reproduce by laying eggs.

The average life-span of these frogs ranges from 5 to 15 years with some individuals recorded to have lived for 20-25 years. They shed their skin every season, and eat their own shedded skin.

Although lacking a vocal sac, the males make a mating call of alternating long and short trills, by contracting the intrinsic laryngeal muscles. Females also answer vocally, signaling either acceptance (a rapping sound) or rejection (slow ticking) of the male. This frog has smooth slippery skin which is multicolored on its back with blotches of olive gray or brown. The underside is creamy white with a yellow tinge.

Male and female frogs can be easily distinguished through the following differences. Male frogs are usually about 20% smaller than females, with slim bodies and legs. Males make mating calls to attract females, sounding very much like a cricket calling underwater. Females are larger than the males, appearing far more plump with hip-like bulges above their rear legs (where their eggs are internally located). While they do not sing or call out like males do, they do answer back (an extremely rare phenomenon in the animal world).

Both males and females have a cloaca, which is a chamber through which digestive and urinary wastes pass and through which the reproductive systems also empty. The cloaca empties by way of the vent which in reptiles and amphibians is a single opening for all three systems.

In the wild

In the wild, *Xenopus laevis* are native to wetlands, ponds and lakes across arid/semiarid regions of southern Africa. *Xenopus laevis* and *Xenopus muelleri* occur along the western boundary of the Great African Rift. The people of the sub-Saharan are generally very familiar with this frog, and some cultures use it as a source of protein, an aphrodisiac, or as fertility medicine. Wild *Xenopus* are much larger than their captive bred counterparts.

Use in research

Although *X. laevis* does not have the short generation time and genetic simplicity generally desired in genetic model organisms, it is an important model organism in developmental biology. *X. laevis* takes 1 to 2 years to reach sexual maturity and, like most of its genus, it is tetraploid. However, it does have a large and easily manipulable embryo. The ease of manipulation in amphibian embryos has given them an important place in historical and modern developmental biology. A related species, *Xenopus tropicalis*, is now being promoted as a more viable model for genetics. Roger Wolcott Sperry used *X. laevis* for his famous experiments describing the development of the visual system. These experiments led to the formulation of the Chemoaffinity hypothesis.

Xenopus oocytes provide an important expression system for molecular biology. By injecting DNA or mRNA into the oocyte or developing embryo, scientists can study the protein products in a controlled system. This allows rapid functional expression of manipulated DNAs (or mRNA). This is particularly useful in electrophysiology, where the ease of recording from the oocyte makes expression of membrane channels attractive. One challenge of oocyte work is eliminating native proteins that might confound results, such as membrane channels native to the oocyte. Translation of proteins can be blocked or splicing of pre-mRNA can be modified by injection of Morpholino antisense oligos into the oocyte (for distribution throughout the embryo) or early embryo (for distribution only into daughter cells of the injected cell).

Extracts from the eggs of *X. laevis* frogs are also commonly used for biochemical studies of DNA replication and repair, as these extracts fully support DNA replication and other related processes in a cell-free environment which allows easier manipulation.

The first vertebrate ever to be cloned was an African clawed frog.

Additionally, several African clawed frogs were present on the space shuttle Endeavour (which was launched into space on September 12, 1992) so that scientists could test whether reproduction and development could occur normally in zero gravity.

X. laevis is also notable for its use in the first well-documented method of pregnancy testing when it was discovered that the urine from pregnant women induced *X. laevis* oocyte production. Human chorionic gonadotropin (HCG) is a hormone found in substantial quantities in the urine of pregnant women. Today, commercially available HCG is injected into *Xenopus* males and females to induce mating behavior and to breed these frogs in captivity at any time of the year.

As pets

Xenopus laevis have been kept as pets and research subjects since as early as the 1950s. They are extremely hardy and long lived, having been known to live up to 20 or even 30 years in captivity.

African Clawed Frogs are frequently mislabeled at African Dwarf Frogs in pet stores. The astute pet owner will recognize the difference, however, because of the following characteristics:

- Dwarf frogs have four webbed feet. African Clawed Frogs have webbed hind feet while their front feet have autonomous digits.
- African Clawed frogs are often found in albino varieties. No such morphology exists for the African Dwarf Frog.
- African Dwarf Frogs have eyes positioned on the side of their head, while African Clawed Frogs have eyes on the top of their heads
- African Clawed Frogs have curved, flat snouts. The snout of an African Dwarf Frog is pointed.

As a pest

African Clawed Frogs are voracious predators and easily adapt to many habitats. For this reason, they can easily become harmful invasive species. They can travel short distances to other bodies of water, and some have even been documented to survive mild freezes. They have been shown to devastate native populations of frogs and other creatures by eating their young.

In 2003, *Xenopus* frogs were discovered in a pond at San Francisco's Golden Gate Park. Much debate now exists in the area on how to exterminate these creatures and keep them from spreading. It is unknown if these frogs entered the San Francisco ecosystem through intentional release or escape into the wild.

Due to incidences in which these frogs were released and allowed to escape into the wild, African Clawed Frogs are illegal to own, transport or sell without a permit in the following US states: Arizona, California, Kentucky, Louisiana, New Jersey, North Carolina, Oregon, Virginia, Hawaii, Nevada, and Washington state. However, it is legal to own *Xenopus laevis* in Canada.

African dwarf frog

African dwarf Frogs	

Hymenochirus boettgeri

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibian
Subclass:	Lissamphibia
Superorder:	Batrachia
Order:	Anura
Family:	Pipidae
Genus:	***Hymenochirus*** Boulenger, 1896

Species

Hymenochirus boettgeri
Hymenochirus boulengeri
Hymenochirus curtipes
Hymenochirus feae

African dwarf frogs are small aquatic frogs native to parts of Africa, spreading from tropical to subtropical areas primarily in the Congo region.

Description

African dwarf frogs live nearly all of their lives underwater, but need to rise to the surface to breathe air because they have lungs and not gills. These frogs are fairly small in size and do not weigh more than a few ounces. These frogs vary in color, for the most part ranging from olive green to brown with black spots. The average life expectancy of these frogs can be up to 5 years, but they can live as long as 20 years; they are known to grow to a maximum of 2½ inches long. When young, African dwarf frogs can be mistaken and sold as African clawed frogs, African frogs of the genus *Xenopus*, which are larger and more aggressive than the dwarf.

All species of Pipidae are tongueless, toothless and completely aquatic. They use their hands to shove food in their mouths and down their throats and a hyobranchial pump to draw or suck food into their mouth. Pipidae have powerful legs for swimming and lunging after food. They also use the claws on their feet to tear pieces of large food. They lack true ears but have lateral lines running down the length of the body and underside; this is how they can sense movements and vibration in the water. They use their sensitive fingers, sense of smell, and lateral line system to find food. They are scavengers and will eat anything living, dying or dead and any type of organic waste.

note black claws on hind legs

These frogs have tiny black claws on their hind legs, which caused one of their discoverers, Oskar Boettger, to originally call them 'African dwarf clawed frogs'. But they quickly lose these black tips in the sharp pebble environment of the average aquarium and are more commonly called 'African dwarf frogs' today.

In the wild

The African dwarf frog habitat in the wild consists of shallow rivers, creeks and ponds during the dry season and in the flooded areas of the forests during the wet season. These creatures prefer eating and playing near the bottom, where they can be safe from predators and hide while they sleep.

Males are slim and will develop a small gland behind each of their front legs; this gland is not very well understood but is believed to play some part in mating. The gland is a small white spot on both sides, a minor outward bulge on both sides of the frog. Males are known to “sing” or “hum” during mating or when excited. Only the males are known to do this, although they will sometimes “hum” even if there is no intention of mating. The females of this species are 20% larger than males when fully mature. They have pear-shaped bodies, as their abdomens will fill with eggs as they reach a mating stage. Another distinction is that females will have a more pronounced genital region, called an ovipositor.

African dwarf frogs mate during what is called amplexus. In amplexus, the male grabs the female around the abdomen just in front of her back legs. The female becomes motionless and her forearms may twitch sporadically. Amplexus usually happens at night after one or more nights of “humming” by the male. During amplexus, the female does all the swimming. The female lays her eggs on the surface of the water, one at a time while towing the male. She will swim to the bottom between layings. The male is fertilizing the eggs during this time by releasing sperm into the water. Amplexus can last for several hours. When the female has laid all her eggs she signals the male to release her by going motionless. After several minutes of being motionless the male will release the female and she will return to her normal behavior.

As pets

African dwarf frogs are commonly found as pets. They first became popular in the 1960s and have spread to the pet trade all over the world. They are desirable pets because of their low maintenance requirements compared to other amphibians. African clawed frogs are often sold erroneously as African dwarf frogs. The astute pet owner will recognize the difference, however, because of the following characteristics:

- Dwarf frogs have four webbed feet. African clawed frogs have webbed hind feet while their front feet have autonomous digits.
- African clawed frogs are often found in albino varieties. No such morphology exists for the African dwarf frog.
- African dwarf frogs have eyes positioned on the side of their head, while African clawed frogs have eyes on the top of their heads
- African clawed frogs have curved, flat snouts. The snout of an African dwarf frog is pointed.

African dwarf frogs are very active and rarely will sit still for any period of time. When stationary, the African dwarf frog has been known to float in one spot, with its legs and arms completely outstretched, resting on one foot. This is a normal behaviour called "burbling". Sometimes they will just float with arms and legs spread out, drifting on the surface. African dwarf frogs are generally peaceful with animals of their own size but their diet sometimes includes smaller animals. Other fish are known to eat the eggs of these frogs. African dwarf frogs spend most of their time eating or playing near the bottom of the water, where they feel safe from predators. Most frogs will sleep up to twelve hours a day, provided there is no potential threat of predators.

It is commonly suggested that these frogs be kept in groups of two or more due to their social nature. A minimum of one gallon per frog is needed to keep these frogs, as they are very active and need the space to move. Despite being fully aquatic, the African dwarf frog still needs to be able to reach the surface to breathe. Very high or deep tanks over 20 inches in height are not recommended. These amphibians are not great swimmers, so water currents should be kept low. Very deep tanks may pose a challenge to their ability to breathe. In the wild, the Congo forest floods yearly to a depth of 24 or more inches. So anything less than that will be suitable. They also should be kept in an enclosure with a secure cover to prevent escape and plenty of hiding spaces as in the wild they tend to be prey to a variety of animals and causes skittish behaviour in open spaces. The optimum water temperature for aquatic frogs is 75–82 °F. The pH value in the tank should be maintained between 6.5 – 7.5.

Dwarf frog shown in an aquarium

These frogs come out of the water every once in a while, but they cannot survive for longer than 20 minutes in low humidity as they will dry out.

They are compatible with most bottom feeders and algae eaters. Respectful tropical fish can also be used as tank mates, although aggressive fish will often fight or injure the frogs. As African dwarves are slow eaters, it is not uncommon for tankmates to eat all the food while the frogs go hungry. If this becomes a problem, methods of delivering the food directly to the bottom of the tank (such as with a turkey baster) should be employed to ensure the frogs are adequately fed.

African dwarf frogs do not have teeth, so they swallow their food whole. Common foods include blood worms, brine shrimp, water fleas (daphnia), shrimp, and various brands of commercial frog food. These frogs will also eat mosquito larvae, black worms, guppy fry, glassworms, tadpole bites, reptomin, gammarus, dried krill, baby shrimp, frozen beefheart, small fish, and small earthworms. On rare occasions these frogs will eat water snails and brittle shells. African dwarf frogs are bottom-feeders and are rarely seen eating at the surface of the water.

Care should be taken when handling African dwarf frogs, especially when considering them as a pet for young children. These frogs should never be held outside the tank, both for the safety of the frog and as they may be carriers of *Salmonella*.

African Foam-nest Tree Frog

African Foam-nest Tree Frog

Conservation status

Least Concern (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia

Order:	Anura
Suborder:	Neobatrachia
Family:	Rhacophoridae
Genus:	*Chiromantis*
Species:	***C. rufescens***

Binomial name

Chiromantis rufescens
(Günther, 1869)

The **African Foam-nest Tree Frog** (*Chiromantis rufescens*) is a frog that lives in the tropical rainforests of Central Africa. Its upper body is a brownish color, tinged rust, and it has small dark spots around its head and pelvis. The frog lives in trees, and builds its nest on branches overhanging water. It is called the *foam-nest* tree frog because its nest consists of air bubbles, wrapped in leaf. When its larvae hatch, they fall into the water below, where they grow from tadpoles into frogs. It absorbs moisture off hands when touched. It also changes colour at night in order to be camouflaged.

Ventral view

Foam nest

Chapter- 9

Amphibians of Central America

Dermophis costaricensis

Dermophis costaricensis	
Conservation status	

Data Deficient (IUCN 3.1)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	Gymnophiona
Family:	Caeciliidae
Genus:	*Dermophis*
Species:	***D. costaricensis***

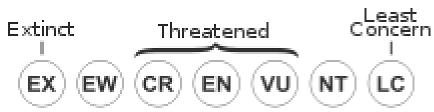
Binomial name

Dermophis costaricensis
Taylor, 1955

Dermophis costaricensis is a species of amphibian in the Caeciliidae family. It is endemic to Costa Rica. Its natural habitats are subtropical or tropical moist montanes, plantations , rural gardens, and heavily degraded former forest.

Dermophis glandulosus

Dermophis glandulosus	
Conservation status	



Data Deficient (IUCN 3.1)

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	Gymnophiona
Family:	Caeciliidae
Genus:	*Dermophis*
Species:	***D. glandulosus***

Binomial name

Dermophis glandulosus
Taylor, 1955

Synonyms

Dermophis balboai Taylor, 1968

Dermophis glandulosus is a species of amphibian in the Caeciliidae family. It is found in Colombia, Costa Rica, and Panama. Its natural habitats are subtropical or tropical moist lowland forests, subtropical or tropical moist montanes, plantations , rural gardens, and heavily degraded former forest.

Dermophis parviceps

Dermophis parviceps	
Conservation status	

Least Concern (IUCN 3.1)

Scientific classification	
Kingdom:	Animalia

Phylum:	Chordata
Class:	Amphibia
Order:	Gymnophiona
Family:	Caeciliidae
Genus:	*Dermophis*
Species:	***D. parviceps***

Binomial name

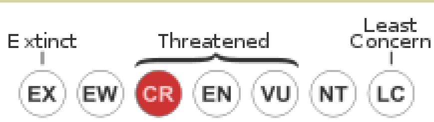
Dermophis parviceps
(Dunn, 1924)

Dermophis parviceps is a species of amphibian in the Caeciliidae family. It is found in Costa Rica and Panama. Its natural habitats are subtropical or tropical moist lowland forests and subtropical or tropical moist montanes. It is threatened by habitat loss.

Morelet's Treefrog

Morelet's Treefrog

Conservation status



Critically Endangered (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata

Class:	Amphibia
Order:	Anura
Family:	Hylidae
Genus:	*Agalychnis*
Species:	***A. moreletii***

Binomial name

Agalychnis moreletii
(Duméril, 1853)

The **Morelet's Treefrog** (***Agalychnis moreletii***) is a species of frog in the Hylidae family. It is found in Belize, El Salvador, Guatemala, Honduras, and Mexico. Its natural habitats are subtropical or tropical moist lowland forests, subtropical or tropical moist montanes, freshwater marshes, and intermittent freshwater marches. It is threatened by habitat loss.

Description

The Morelet's Tree Frog (Agalychnis moreletii) is a fairly uncommon frog which has a green body, black eyes and a red or pink underbelly. They belong to the order Anura, which encompases all frogs, the family Hylidae which encompasses specifically tree frogs, the genus agalychnis, or tree frogs native to Central and South America and species moreletii. They have also been called black-eyed leaf frogs and popeye hyla. They are found in moist subtropical lowland mountainous forests and wetland habitats of Belize, Brazil, El Salvador, Guatemala, Honduras and Mexico. They have been collected on the Atlantic and Pacific slopes of Veracruz, Chiapas, the Maya mountains of Belize, northwestern Honduras and El Salvador. They can live in pristine or disturbed habitats and will breed in temporary or permanent bodies of water. They have an extended breeding season during the summer months. They deposit clutches of 50 to 75 eggs on vegetation or rocks over water. The eggs of the Morelet's Tree Frog have a green pigment and when they hatch, the larvae fall into the water to complete their development into frogs.

Threats

The Morelet's Tree Frog was abundant within its range and were kept as pets internationally. However it is currently listed as critically endangered on the IUCN Red List as of 2001 because of habitat destruction and disease. Industry and agriculture are thought to be the main causes of lowland montane forest destruction. The population of Morelet's Tree Frogs are also being decimated due to a disease called Chytridiomycosis, which is an infectious disease that kills amphibians. Chytridiomycosis and habitat destruction are projected to cause the population to decline over 80% in the next 10 years. In some regions, the frogs have gone extinct completely. For example, a study done in 2004, has claimed that Morelet's Tree Frog may be extirpated from the region of Southern Mexico. Small snakes also are predators of the Morelet's Tree Frog. Of course there is also the threat of pollution which causes the waters to become more acidic causing direct negative impacts on the tadpoles and frogs. In fact there are about nine different levels of the scale and how close to extinction the species is, this frog was a seven (Critically Endangered), it is two levels ahead of extinction! According to the U.S. Delegation website, “U.S. Supports Amphibian and Reptile Proposals That Receive International Protection.” This is positive news because it means that the governments agree on keeping these amphibians and reptiles from becoming extinct and are taking steps necessary to prevent their extinction. It is because of harmful chemicals like chlorofluorocarbons (CFCs) that’s the Earth’s ozone layer has diminished, which results in increased levels of ultraviolet radiation penetrating through the Earth’s surface. “Exposure to UV-B radiation causes genetic mutations that can prevent normal development or kill eggs. Increased UV-B levels particularly affect the many frog species whose eggs lack shells and float on the exposed surfaces of ponds. Tadpoles and frogs are also at risk, because of their thin delicate skins.”

Conservation Measures

Morelet's Tree Frogs are dying at a rapid rate. Their survival is dependent upon several factors due to their human and disease caused population decline. Some conservation measures are in place, while others are still in need of implementation or research. A number of protected parks have been created to curb habitat destruction in areas of Central America and Mexico. Taxonomic research is currently in place to further understand the population's status. More data is needed, however, on a temporal and spatial scale to determine trends in the population of Morelet's Tree Frogs.