

AMPHIBIANS PART II: FROG DIVERSITY

GENERAL INFORMATION

Anura (the frogs) is the most speciose and diverse group of amphibians. Eighty-eight percent of the 7,615 described amphibian species and 73% of amphibian families are frogs. Frogs are found on all continents except Antarctica (but they get close) and many oceanic islands. Representatives can be found in a range of ecosystems including arctic tundra, deserts, mountains... but the greatest diversity of species and families is centered around the moist tropics. As a group, the anurans are distinctive in that they share all of the standard amphibian characteristics but are differentiated from Caudata and Gymnophiona by the combination of the following traits: 1) All lack a true tail in adulthood; 2) Two pairs of well-developed limbs that may or may not be specialized for jumping; 3) Reduced number of vertebrae; 4) Specialized pelvic girdle with elongated ilium and urostyle.

DISTRIBUTION AND DIVERSITY

Distribution: Americas from arctic circle to Tierra del Fuego, Africa, Eurasia, Indian subcontinent, Madagascar, Indochina, Japan, Australasia, New Zealand

Diversity: 55 families, 447 genera, ~6,716 species

US Diversity: 10 families, 18 genera, 104 species

NM Diversity: 6 families, 10 genera, 24 species

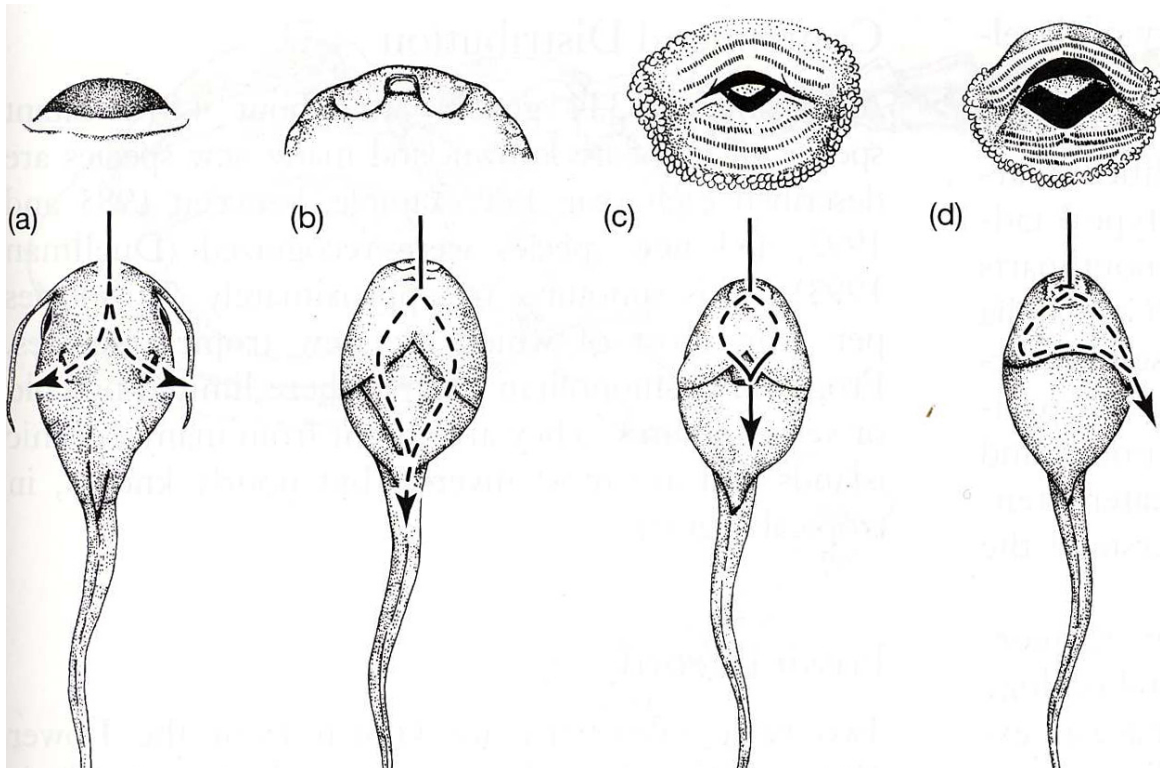
A NOTE ON TAXONOMY

There have been a lot of recent changes to the taxonomy of Anurans. Consequently, the taxonomy that we follow differs quite a bit from that used in the textbook. The largest revision to the group occurred in 2006 (Frost et al.) and although this was a tremendous contribution to amphibian systematics, subsequent work has focused on correcting a number of mistakes and taxonomic inconsistency introduced by Frost et al. 2006. There have also been a lot of new discoveries since 2006 that have allowed systematists to make more accurate inferences regarding evolutionary relationships. We will follow the taxonomy of AmphibiaWeb (<http://www.amphibiaweb.org/taxonomy/index.html>), which is largely based on suggestions of Blackburn and Wake 2011 and Pyron and Wiens 2011. (Simplified phylogeny on page 3).

DEVELOPMENT AND LARVAL IDENTIFICATION

Most frogs have aquatic larvae that undergo metamorphosis. These aquatic larvae (tadpoles) vary drastically in both morphology and developmental rate (time to metamorphosis) between species. Some lineages have evolved a different strategy—direct development, skipping the tadpole stage altogether. Direct developers emerge from eggs as froglets, this offers advantages in certain situations. Larval characteristics are one important element used for developing phylogenetic hypotheses of relationships among frogs. We will explore basic tadpole biology to get a grasp on major differences in larval types, and how these differences help characterize frog families.

There are four general morphological types of tadpoles. For each tadpole type, a ventral view of the oral disc and the head-body are shown. Dashed lines show the path of water flow, and arrows indicate general position of spiracle and direction of water flow from the oral cavity out of the body (Fig. 3-18, p. 71, Pough *et al.* 2004). Tadpole types are initially separated by presence of keratinous mouthparts (Types III & IV).



Type I: No keratinous mouthparts, paired spiracles, mouth occasionally with barbells (Xenopus)

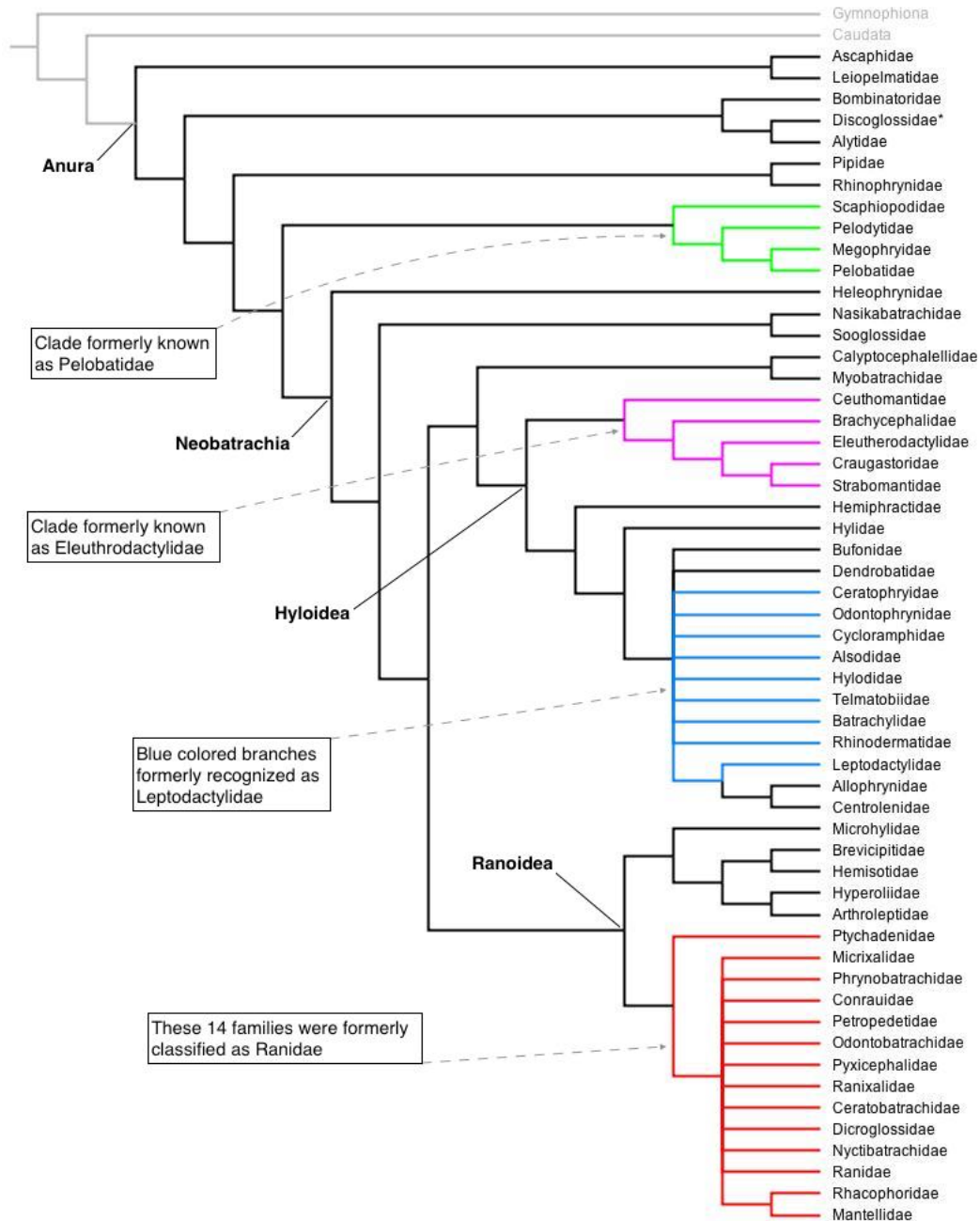
Type II: No keratinous mouthparts, single medial posterior spiracle, lack barbells

Type III: Keratinous mouthparts present, midventral spiracle

Type IV: Keratinous mouthparts present, sinistral (left side) spiracle (Ceratophrys)

FAMILY IDENTIFICATION, DISTRIBUTION AND DIVERSITY

Our anuran collection is respectable but is by no means complete. In keeping with the previous lab, I provide information for all 55 recognized anuran families but we will focus on those for which we have representatives (in bold text below) and may discuss some of the more interesting families that are not represented. You will see that some are easily identifiable by external morphology while others are nearly impossible. For difficult families, you will need a combination of knowledge including distribution, larval type, and/or life history information to make a confident identification. This information will be provided in practical questions. Again, pay attention to New Mexico species, you will be asked to identify these to species (we will revisit them in two weeks).



Phylogeny of the frogs adapted from Pyron and Wiens 2011.

**AmphibiaWeb's current taxonomic scheme recognizes discoglossid frogs as a subfamily within the Alytidae.*

Family: Ascaphidae

Diversity: 1 genus, 2 species

Distribution: Cold, fast-flowing streams from British Columbia to N. California, east to Rocky Mountains of Idaho and Montana

Aquatic Larvae: Type III

Traits: Internal fertilization via “tail”, vertical pupil, 9 presacral vertebrae; cartilaginous sternum, omosternum; urostyle with one condyle; free ribs (3rd, 4th, and 5th vertebrae); pectoral girdle arciferal; clavicle overlies scapula; maxilla and premaxillae contain teeth

Specimens:

Family: Leiopelmatidae

Diversity: 1 genus, 4 species

Distribution: New Zealand—only frog genus native to NZ

Aquatic Larvae: None, direct developers

Traits: Similar to sister taxon, Ascaphidae, share several “primitive” characteristics and poses inscriptional ribs (cartilage embedded in abdominal muscle), lack a protrusible tongue, and use alternating kicks to swim

***Family:* Bombinatoridae**

***Diversity:* 2 genera, 10 species**

***Distribution:* Disjunct distribution in Europe, W. Asia, Korea, China, Vietnam, Philippines and Borneo**

***Aquatic Larvae:* Type III**

***Traits:* Dorsoventrally flattened, pupil triangular or vertically elliptical, further diagnosis by internal morphology. Aposematic coloration (*Bombina*); *Barbourula kalimantanensis* world’s only lungless frog**

Specimens:

Family: Alytidae

Diversity: 3 genera, 11 species

Distribution: Western Europe and extreme north Africa

Aquatic Larvae: Type III

Traits: Superficially toad-like, terrestrial, males attach egg clutches to their back and thighs and carries them until hatching at which point tadpoles are deposited into a waterbody

***Family:* Pipidae**

***Diversity:* 4 genera, 41 species**

***Distribution:* Aquatic, Africa and South America**

***Aquatic Larvae:* Type 1 or direct developers**

***Traits:* Fully aquatic, dorsoventrally flattened body, lack tongue, fully webbed hind feet, small dorsally oriented eyes, teeth are either non-pedicellate, reduced in number or absent**

Specimens:

***Family:* Rhinophrynidae**

***Diversity:* Monotypic**

***Distribution:* Extreme S Texas to Costa Rica**

***Aquatic Larvae:* Type I**

***Traits:* Small head with a pointed snout, globular body, small eyes and lack of teeth. Ant specialist with ant-eater-like tongue that protrudes through a narrow opening at the front of the mouth.**

Specimens:

***Family:* Scaphiopodidae**

***Diversity:* 2 genera, 7 species**

***Distribution:* SE USA and western North America from Canada to Isthmus of Tehuantepec**

***Aquatic Larvae:* Type IV**

***Traits:* American spadefoots: keratinized spade on each hind foot, plump bodies, and large eyes (note: spade or similar structure present many other frogs). Most species in arid regions, breed in temporary pools. Larval development is rapid is adaptation to the extreme ephemerality of arid-land water bodies.**

Specimens:

Family: Pelodytidae

Diversity: 1 genus, 3 species

Distribution: S Belgium through Iberian Peninsula, also in Caucasus region

Traits: Formerly classified under Pelobatidae, slightly resemble spadefoots but differentiated by: astragalus and calcaneum fused; parahyoid bone in hyoid apparatus; vertebrae I & II fused; three tarsalia bones in foot.

Family: Pelobatidae

Diversity: 1 genus, 4 species

Distribution: W Eurasia, NW Africa

Traits: Old world morphological and ecological analogs to American spadefoots (Scaphiopodidae)

Family: Megophryidae

Diversity: 10 genera, 199 species

Distribution: Pakistan, India, Indochina, Sunda Islands, Philippines, Borneo

Traits: Formerly Microhylidae, this group comprises a diverse assemblage of mostly dead-leaf-mimicing species characterized by a combination of skeletal characteristics

NEOBATRACHIA

Family: Heleophrynidae

Diversity: 2 genera, 6 species

Distribution: Restricted to South Africa

Traits: Large eyes, vertical pupils, and triangular toe discs

Family: Nasikabatrachidae

Diversity: Monotypic

Distribution: Western Ghats region of India

Traits: Specialized burrower with globose body and small head with pointed snout, purple skin

Family: Sooglossidae

Diversity: 2 genera, 4 species

Distribution: Seychelles endemic

Traits: Small, sister to Nasikabatrachidae, digits end in small, pointed discs, sesamoid bone in the heel region.

Family: Calyptocephalellidae

Diversity: 2 genera, 5 species

Distribution: Chile

Traits: Superficially toad-like

Family: Myobatrachidae

Diversity: 21 genera, 134 species

Distribution: New Guinea, Australia, Tasmania

Traits: Diverse morphology—some ranid-like, most specialized burrowers many toad-like or convergent with American spadefoots. *Myobatrachus* shows extreme adaptations for burrowing.

HYLOIDEA

Family: Ceuthomantidae

Diversity: 1 genus, 4 species

Distribution: Guyana highlands of South America

Aquatic Larvae: None, direct developers

Traits: T-shaped terminal phalanges, lack intercalary elements at digit tips, poorly ossified neurocranium, very large neopalatine, notched digital discs on fingers and toes, lack vomerine teeth, paired lipid-containing protrusions of unknown function in post-temporal and sacral regions

Family: Brachycephalidae

Diversity: 2 genera, 64 species

Distribution: Brazil and N. Argentina

Aquatic Larvae: None, all are direct developers

Traits: Recognized on basis of molecular divergence, morphology not useful in diagnosing this family or uniting the two genera. *Brachycephalus*: toad-like but lacking Bidder's organ, digits reduced to 2 on hands and 3 or 4 on feet. *Ischnocnema*: nearly indistinguishable from some *Craugastor*.

***Family:* Eleutherodactylidae**

***Diversity:* 4 genera, 214 species**

***Distribution:* Southern USA through Amazon Basin, West Indies and Caribbean**

***Aquatic Larvae:* None, direct developers—*Eleutherodactylus jasperi* is ovoviviparous**

***Traits:* Terminal phalanges T-shaped; prominent external glands absent (lumbar glands present in some *Eleutherodactylus*); vocal sac (male) either single or paired and subgular, single and pectoral, or absent; males lack nuptial pads; hands unwebbed; feet unwebbed or webbed basally; terminal digits usually expanded; inner and outer metatarsal tubercles present, inner tubercle not spade-like**

Specimens:

***Family:* Craugastoridae**

***Diversity:* 3 genera, 122 species**

***Distribution:* Southern USA to NW South America, SE Brazil**

***Aquatic Larvae:* None, direct developers, terrestrial or arboreal egg deposition, often with some parental care**

***Traits:* Finger I longer than Finger II (most); unwebbed fingers; lack prominent external glands on body; digit tips expanded into pads with circummarginal grooves; inner and outer metatarsal tubercles; tympanic membrane and annulus usually distinct**

Specimens:

Family: Strabomantidae

Diversity: 20 genera, 654 species

Distribution: South America—Amazon and Orinoco Basins, Guyana Shield, Chaco region, Brazilian Atlantic coastal forest, highest diversity in eastern Andes

Traits: Closely related to Craugastoridae and formerly classified as Eleutherodactylidae. Characterized by fully developed and free first toe; single, subgular vocal sac (males), vocal slits present in vocal sac; skin pad on underside of toe/fingertips defined by circumferential groove (absent in terrestrial species).

Family: Hemiphractidae

Diversity: 6 genera, 104 species

Distribution: Brazil, Colombia, Ecuador, Peru, and Panama

Aquatic Larvae: None, direct developers

Traits: Treefrog-like, formerly classified under Hylidae, eggs reared in dorsal pouch

***Family:* Hylidae**

***Diversity:* 51 genera, 964 species**

***Distribution:* North, Central and South America, Eurasia, Australia and New Guinea, and extreme north Africa. Absent from most of Africa, Indian subcontinent, Indochina, and Siberia.**

***Aquatic Larvae:* Type IV**

***Traits:* Physical appearance highly variable, characteristically treefrog-like with long, slender limbs, expanded toe pads and hook-like terminal phalanges that facilitate an arboreal lifestyle. One genus and several species in several genera have independently evolved to occupy more terrestrial habitats.**

Specimens:

Family: Bufonidae

Diversity: 51 genera, 569 species

Distribution: Temperate to tropical regions worldwide, invasive south of Wallace's line (i.e., Australia)

Aquatic Larvae: Variable, aquatic stage in most, some direct developers and 2 genera are viviparous

Traits: Overall size and shape extremely variable, most with dry, rugose to warty skin texture, and all share the following traits: Bidder's organ present; teeth absent; constrictor posterior muscle absent; depressor mandibulae muscle originating from squamosal; inguinal fat bodies; skull highly ossified

Specimens:

Family: Dendrobatidae

Diversity: 18 genera, 307 species

Distribution: Central and South America

Aquatic Larvae: Type IV

Traits: These are the "poison-dart" frogs of the Neotropics. Many species are brightly colored and produce strong toxins in their skin. Dendrobatids are quite diverse, but are usually diurnal frogs that lay eggs on land. They are often territorial and exhibit parental care.

Specimens:

Family: Leptodactylidae

Diversity: 15 genera, 209 species

Distribution: Mexico to southern South America, Caribbean/West Indies

Aquatic Larvae: Type IV

Traits: Diverse group of terrestrial to semiaquatic frogs, Leptodactylidae had been a repository for all difficult to place Hyloid frogs from Central and South America and was only recently split on the basis of molecular characters. Consequently, a good morphological picture of the group is not available.

Specimens:

Family: Ceratophryidae

Diversity: 3 genera, 12 species

Aquatic Larvae: Variable, some carnivorous

Distribution: South America—including Caribbean and Amazonian lowlands, the Gran Chaco, Cerrado, Atlantic coastal forests

Traits: Disproportionately large head and gape, other traits shared with former Leptodactylids

Specimens:

Family: Odontophrynidae

Diversity: 3 genera, 52 species

Distribution: Eastern and southern South America

Traits: Most are toad-like, *Proceratophrys* convergent with Ceratophryidae, formerly Leptodactylidae

Family: Cycloramphidae

Diversity: 2 genera, 34 species

Distribution: Brazil, Atlantic coastal forests

Traits: Formerly Leptodactylidae—small (~30mm SVL), typical frog body plan, usually with rough skin

Family: Alsodidae

Diversity: 3 genera, 30 species

Distribution: S Brazil to Patagonia

Traits: Formerly Leptodactylidae

Family: Hylodidae

Diversity: 3 genera, 46 species

Distribution: NW Brazil to N Argentina

Traits: Ambiguous phylogenetic placement, typical frog body plan, may have smooth or tuberculate skin

Family: Telmatobiidae

Diversity: 2 genera, 63 species

Distribution: Andes

Traits: Formerly a subfamily under Leptodactylidae, the group comprises medium to large frogs with a typical frog body plan, several species like the Lake Titicaca Frog (*Telmatobius culeus*) are aquatic.

Family: Batrachylidae

Diversity: 4 genera, 15 species

Distribution: Central and southern Chile and Argentina

Traits: Formerly lumped with horned frogs under Leptodactylidae—typical frog body plan

Family: Rhinodermatidae

Diversity: 2 genera, 3 species

Distribution: Central coast of Chile to extreme western Argentina

Traits: Not especially distinct from close relatives like Leptodactylidae except for unique breeding practices in which eggs are deposited on land and either transported to water by mouth or, in the case of *Rhinoderma darwinii*, reared in the male's vocal sac.

Family: Allophrynidae

Diversity: 1 genus, 3 species

Distribution: Venezuela, Suriname, Guyana, French Guiana, and Brazil

Aquatic Larvae: Type IV

Traits: Superficially tree-frog-like, pupil horizontal, 8 presacral vertebrae, ribs absent, urostyle free, pectoral girdle arciferous, sternum cartilaginous and omosternum absent, clavicle does not overlie scapula, teeth absent, intercalary cartilage between final and penultimate phalanx, sartorius muscle separate and distinct

***Family:* Centrolenidae**

***Diversity:* 12 genera, 154 species**

***Distribution:* Montane, S. Mexico to Bolivia and east to Surinam; Atlantic coastal forests of Brazil**

***Traits:* Tree frog-like, coloration is some shade of green, ventral skin transparent, other characters include: astragalus and calcaneum fused; dilated medial process on third metacarpal; T-shaped terminal phalanges; 8 presacral vertebrae; ribs absent; pectoral girdle arciferous; palatines present. Skin reflects same/similar IR wavelength as plants, egg masses deposited on vegetation above water**

Specimens:

RANOIDEA

***Family:* Microhylidae**

***Diversity:* 61 genera, 599 species**

***Distribution:* Americas, India, SE Asia to New Guinea and N Australia**

***Aquatic Larvae:* Type II usually, some direct developers**

***Traits:* Though the family is quite old and diverse, these frogs are usually quite distinct in having a narrow, pointed head with a fold at the posterior end and edentate, slit-like mouths.**

Specimens:

Family: Brevicipitidae

Diversity: 5 genera, 34 species

Distribution: eastern and southern parts of sub-Saharan Africa

Aquatic Larvae: None, all believed to be direct developers

Traits: Formerly placed in Microhylidae, extremely short head, body often rotund, extreme sexual size dimorphism necessitates adhesive amplexus in many species, group united by lack of ossified sphenethmoids

Family: Hemisotidae

Diversity: 1 genus, 9 species

Distribution: Tropical savannahs of sub-Saharan Africa

Traits: Globose-bodied with hardened, pointed snout used for burrowing (convergent with Rhinophrynidae)

Family: Hyperoliidae

Diversity: 17 genera, 228 species

Distribution: Sub-Saharan Africa, Madagascar, Seychelles

Traits: Most are treefrog-like, members of this group are diagnosable by the absence of nuptial pads and posterolateral process of hyoid, sternum cartilaginous, dentomentalis muscle present, vertical pupil in most

Family: Arthroleptidae

Diversity: 8 genera, 152 species

Distribution: Sub-Saharan Africa

Aquatic Larvae: Variable, some direct developers

Traits: Morphology is variable, most occur in/on leaf litter near streams, one genus (*Arthroleptis*) is commonly encountered in trees, well-developed, single subarticular tubercles on the digits, all genera have an inner metatarsal tubercle, none have an outer metatarsal tubercle, all have a tympanum (reduced in some)

RANIDAE: *The remaining families form a well-supported, monophyletic clade once called Ranidae. Lumping all of these into a single family would not be incorrect and would actually be simpler. I provide information for Ranidae in its current form and less information for the other, newly recognized families, as many of them are superficially indistinguishable from Ranidae. Mantellidae and Rhacophoridae are the exception*

***Family:* Ranidae**

***Diversity:* 22 genera, 387 species**

***Distribution:* Worldwide, but mostly absent from South America and Australia**

***Aquatic Larvae:* Mostly Type IV**

***Traits:* Typical frog body plan with aquatic tadpoles. Ranids in the US and most ranids in general have long legs, long toes, webbed hind feet, and are terrestrial to semiaquatic primarily in riparian habitat. However, this is a large, diverse group present in a variety of habitats that necessitate more or less association with water, some are even semiarboreal.**

Family: Ptychadenidae

Diversity: 3 genera, 53 species

Distribution: Sub-Saharan Africa

Traits: Basal clade to the group formerly known as Ranidae

Family: Micrixalidae

Diversity: 1 genus, 24 species

Distribution: Western Ghats region of India

Family: Phrynobatrachidae

Diversity: 1 genus, 90 species

Distribution: Sub-Saharan Africa

Family: Conrauidae

Diversity: 1 genus, 6 species

Distribution: Sub-Saharan Africa

Traits: Include the largest extant frog species *Conraua goliath*, reaches SVL of 32cm and a mass of 3300g.

Family: Petropedetidae

Diversity: 3 genera, 12 species

Distribution: Sub-Saharan Africa

Family: Odontobatrachidae

Diversity: 1 genus, 5 species

Distribution: Sub-Saharan west Africa

Family: Pyxicephalidae

Diversity: 12 genera, 80 species

Distribution: Sub-Saharan Africa

Traits: Most ranid-like some toad-like

Family: Ranixalidae

Diversity: 2 genera, 18 species

Distribution: Western Ghats region of India

Family: Ceratobatrachidae

Diversity: 4 genera, 94 species

Distribution: Malaysia, Indonesia, Philippines, New Guinea, Solomon Islands

Aquatic Larvae: None, direct developers

Family: Dicroglossidae

Diversity: 16 genera, 196 species

Distribution: Tropical and subtropical regions of Africa and Asia

Family: Nyctibatrachidae

Diversity: 2 genera, 29 species

Distribution: Western Ghats region of India and Sri Lanka

Family: Mantellidae

Diversity: 12 genera, 212 species

Distribution: Madagascar

Aquatic Larvae: Variable, some direct developers

Traits: Extremely diverse group occupying semi-fossorial, terrestrial, aquatic and arboreal niches. Some are treefrog-like, others ranid-like and the genus *Mantella* is convergent with Dedrobatid frogs.

Family: Rhacophoridae

Diversity: 18 genera, 405 families

Distribution: India, Sri Lanka, China, SE Asia, Indonesia, Japan, East Indies, and Madagascar; one in Africa

Aquatic Larvae: Variable

Traits: Old World treefrogs formerly Ranidae. Highly convergent with the genus *Hyla* (Hylidae). Several members of the genus *Theleuderma* are highly cryptic and resemble moss or lichen while perched.

DISCUSSION QUESTIONS

Why do you think frogs have lost their tail, from an evolutionary point of view?

Convergence has occurred in a number of frog lineages. What are two groups of frogs that have independently evolved similar morphological or behavioral characteristics? Explain.

In many biodiversity hotspots, there are many frog species that are nearly indistinguishable from each other in terms of prey selection and habitat preference, sometimes even morphology. The occupation of a single niche by multiple species should not happen, however, this sort of thing seems to be somewhat common among frogs. How may these species be able to coexist?

What biogeographic patterns are you able to identify among frog groups? Are any of these patterns similar to those observed in salamanders or caecilians?