

## Amphibian Characteristics, Taxonomy, and Evolution



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## Goal of the Lecture

To familiarize students with characteristics of the Class Amphibia, the diversity of extant amphibians, and the fossil record of amphibians.

### Reading Assignments:

- 1) Handouts (Zardoya and Meyer 2001, Laurin 2002)
- 2) Duellman and Trueb: pp. 424-443

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## Lecture Outline

Class Amphibia Characteristics

Extant Amphibia Families

Amphibian Fossil Record

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## What are Amphibians?

Ectothermic tetrapods that have a biphasic life cycle consisting of anamniotic eggs (often aquatic) and a terrestrial adult stage.

Kingdom: Animalia  
 Phylum: Chordata  
 Subphylum: Vertebrata  
 Class: Amphibia (amphibios: "double life")  
 Subclass: Lissamphibia  
 Orders:  
 • Anura (frogs)  
 • Caudata (salamanders)  
 • Gymnophiona (caecilians)




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## Amphibia Characteristics

1) Cutaneous Respiration

- Oxygen and CO<sub>2</sub> Transfer (moist)
- Family Plethodontidae (lungless salamanders)
- Gills (larvae, few adult salamanders), 2 Lungs (adults)



2) Skin Glands

- Mucous Glands (cutaneous respiration, antibiotic properties)
- Granular Glands (toxic secretions - neurotoxins, alkaloids)
  - Paratoid Glands
- Other glands (not in all species)
  - Nuptial
  - Wax




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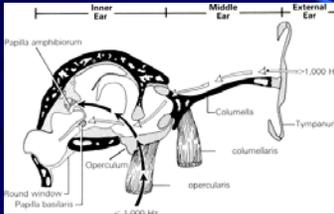
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## Amphibia Characteristics

3) Modifications of middle and inner ear

- Middle ear consists of 2 elements
  - Stapes (columella)
  - Operculum
- Inner ear consists of 2 sensory epithelial patches
  - Papilla bassilaris (>1000 Hz)
  - Papilla amphibiorum (≤1000 Hz)


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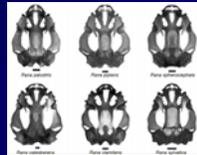
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## Amphibia Characteristics

- 4) Green Rods in Retina (excluding caecilians)
  - Involved in hue discrimination (433 nm = blue light)
  - Other Light Receptors: red rods, single and double cones
- 5) Focus eye by changing position of lens
  - Levator bulbi underlying the eye control elevation
- 6) Bicuspid Pedicellate Teeth
  - Crown (above gum), Pedicel (connected to jawbone)
  - New Crown Emerges from Pedicel
- 7) Reductions in skull bones
  - General trend associated with paedomorphosis
  - (phenotypic change in which adults retain juvenile traits)




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## Modern Orders of Amphibia

- Gymnophiona (caecilians)
  - 167 species

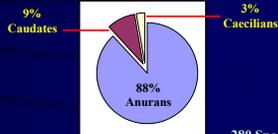


*Ichthyophis kohtaoensis*

- Caudata (salamanders)
  - 559 species



*Plethodon shermani*



280 Species in U.S.  
(86 Species in TN)

- Anura (frogs)
  - 5,420 species



*Dendrobates tinctorius*

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## Gymnophiona

### Characteristics:

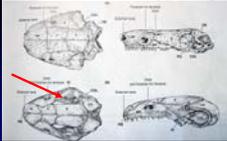
- Limless (pectoral & pelvic girdles absent)
- Elongate and annulated bodies
- Degenerate Eyes (covered with skin or bone)
- Internal Fertilization (phallogenium)
- Tentacle between eye and nostril
- Left lung reduced or absent
- Some with dermal scales
- Distinct skulls

### •Tropical Distribution



•6 Families

### •Stegokrotaphic versus Zygotkrotaphic




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## Gymnophiona

### Families:

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|---|--|
| <p><b>1) Caeciliidae</b> (Common Caecilians)</p> <p><b>•95 species (57%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli</li> <li>•Most Fossorial</li> <li>•No true tail</li> <li>•Stegokrotaphic Skull</li> </ul>  <p><i>Dermophis mexicanus</i></p>                                 | <p><b>2) Ichthyophiidae</b> (Fish Caecilians)</p> <p><b>•38 species (23%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli w/ Secondary &amp; Tertiary</li> <li>•True tail</li> <li>•Stegokrotaphic Skull</li> <li>•Females attend eggs</li> </ul>  <p><i>Ichthyophis kohtaoensis</i></p> |
| <p><b>3) Typhlonectidae</b> (Aquatic Caecilians)</p> <p><b>•14 species (8%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli</li> <li>•No true tail</li> <li>•Zygokrotaphic Skull</li> <li>•Strongly Aquatic</li> <li>•Viviparous</li> </ul>  <p><i>Chthonerpeton indistinctum</i></p> | <p><b>4) Rhinatrematidae</b> (Beaked Caecilians)</p> <p><b>•9 species (5%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli w/ Secondary &amp; Tertiary Grooves</li> <li>•True tail</li> <li>•Zygokrotaphic Skull</li> </ul>  <p><i>Epicrionops</i></p>                                   |

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## Gymnophiona

### Families:

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|---|---|
| <p><b>5) Scolecomorphidae</b> (Tropical Caecilians)</p> <p><b>•6 species (4%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli</li> <li>•No true tail</li> <li>•Zygokrotaphic Skull</li> <li>•Calcified spines on phallodea</li> <li>•Some are viviparous</li> </ul>  <p><i>Scolecomorphus vittatus</i></p> | <p><b>6) Uraeotyphlidae</b> (Indian Caecilians)</p> <p><b>•5 species (3%)</b></p> <ul style="list-style-type: none"> <li>•Primary Annuli w/ Secondary Grooves</li> <li>•True tail</li> <li>•Stegokrotaphic Skull</li> </ul>  <p><i>Uraeotyphlus</i></p> |
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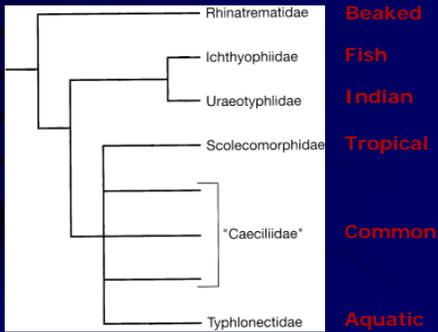
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## Gymnophiona phylogeny




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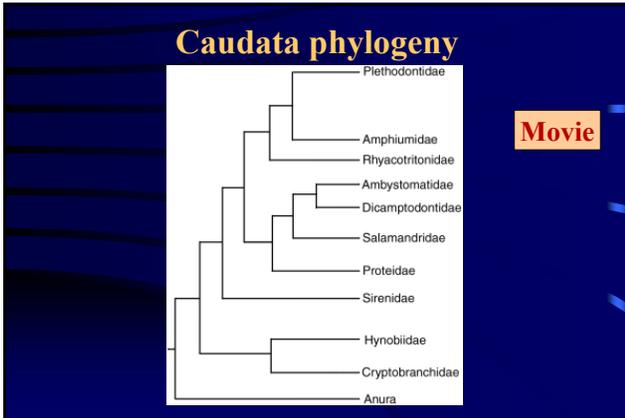
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## Anura

**Characteristics:**

- Shortened Presacral Vertebrae (usually 8)
- Ribs are reduced or absent (2<sup>nd</sup> or 4<sup>th</sup>)
- Presacral Vertebrae Firmly Articulated
- Large Hind Limbs, No tail (except 1 family)
- External Fertilization (usually)
- Flat heads and Large Mouths (usually)
- Vocal Sacs in Males (usually)

**Saltatorial**  
2-10X BL

**Global Distribution**

**29 Families**

**Families:**

**1) Leptodactylidae (Southern Frogs)**

- 1283 species (24%)
- Neo-tropics & subtropics
- Male broods eggs
- Foam nest
- Tadpoles, direct dev., or viviparous



*Eleutherodactylus coqui*

**2) Hylidae (Tree Frogs)**

- 835 species (15%)
- Global Distribution
- Toes disks
- Good climbers, jumpers
- Free swimming tadpoles (most)



*Agalychnis callidryas*

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## Anura

**Families:**

**3) Ranidae (True Frogs)**

- 799 species (14.7%)
- Global (Africa, Asia most)
- Well-developed legs & webbed feet
- Free swimming tadpoles (most)



*Rana catesbeiana*

**4) Bufonidae (True Toads)**

- 493 species (9%)
- Global (Bufo most spp.)
- Cutaneous Glands
- Teeth nearly absent
- Bidder's Organ
- Rudimentary Ovary on Testes



*Bufo cognatus*

**5) Microhylidae (Narrow-mouthed Frogs)**

- 449 species (8%)
- Mostly Tropical, Sub-tropical
- 2-3 Palatal Folds
- Breviceps Secretions
- Stick to Female's Back



*Gastrophryne carolinensis*

**6) Rhacophoridae (Asian Tree Frogs)**

- 288 species (5%)
- Africa, India, SE Asia
- Hanging Foam Nest
- "Flying Frogs"
- Convergent with hylids



*Rhacophorus reinwardtii*

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## Anura

**Families:**

**19) Bombinatoridae** (Fire-bellied Toads & Barbourulas)

•10 species (0.2%)

- Europe; East Asia
- Toxic Skin (unken reflex)
- Barbourulas: Rocky streams



*Bombina orientalis*

**20) Hemisotidae** (Shovel-nosed frogs)

•9 species (0.17%)

- Sub-Saharan Africa
- Burrows head first
- Lay eggs in burrow
- Females dig ditch or transport tadpoles



*Hemisus marmoratus*

**21) Heleophryinidae** (Ghost Frogs)

•6 species (0.1%)

- Southern Africa
- Fast-flowing streams
- Well-developed toe discs, spines, sucker-like oral disc (tadpoles)
- Skeleton Gorge: Cape Town



*Heleophryne regis*

**22) Sooglossidae** (Seychelles Frogs)

•29 species (0.5%)

- Madagascar
- Inguinal amplexus (only Neobatrachid)
- Secretive: litter and rocks
- Direct development & tadpoles on back



*Sooglossus pipilodryas*

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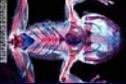
## Anura

**Families:**

**23) Leiopelmatidae** (Leiopelmatids)

•4 species (0.1%)

- New Zealand
- Primitive group
- Do not call (no T, ME, VS)
- Inscriptional ribs



*Leiopelma archeyi*

**24) Pelodytidae** (Parsley Frogs)

•3 species (0.1%)

- Black & Caspian Seas, S. Europe
- Bulging Eyes; Parsley Color
- Females reported vocalizing when amplexed



*Pelodytes punctatus*  
(Mouth-brooding Frogs)

**25) Ascaphidae** (Tailed Frogs)

•2 species (<0.1%)

- NW United States, British Columbia
- Fast moving streams
- Tail: Cloacal Extension
- Internal fertilization
- Most primitive extant family (don't call, 7 yrs to maturation)



*Ascaphus montanus*

**26) Rhinodermatidae**

•2 species (<0.1%)

- Southern South America (Chile)
- Tadpoles Develop in Vocal Sac (male)
- "Rhino-ceros nosed"



*Rhinoderma darwini*

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## Anura

**Families:**

**27) Allophryinidae** (Ruthven's Frog)

•1 species (<0.1%)

- NE South America
- Centrolenidae (related?; foot muscle morphology)
- Little known about its ecology



*Allophryne ruthveni*

**28) Nasikabatrachidae** (Purple Frog)

•1 species (<0.1%)

- India (discovered 2003)
- Fossorial
- Explosive breeders
- Little known



*Nasikabatrachus sahyadrensis*

**29) Rhinophryinidae** (Mexican Burrowing Toad)

•1 species (<0.1%)

- Costa Rica to Rio Grande
- Fossorial
- Explosive breeders
- Termite and ant specialists
- No teeth



*Rhinophrynus dorsalis*

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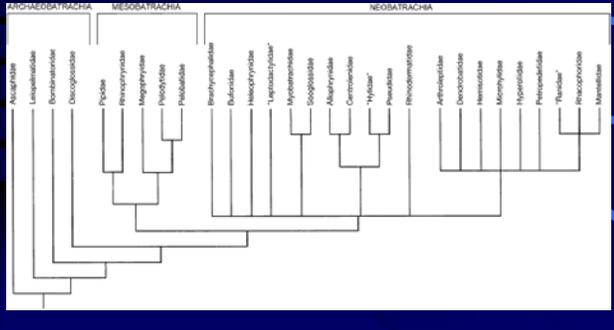
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# Anura Phylogeny




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# Evolutionary history of Amphibians

Events in Geologic History

Fish to Tetrapods

Tetrapods to Amphibians

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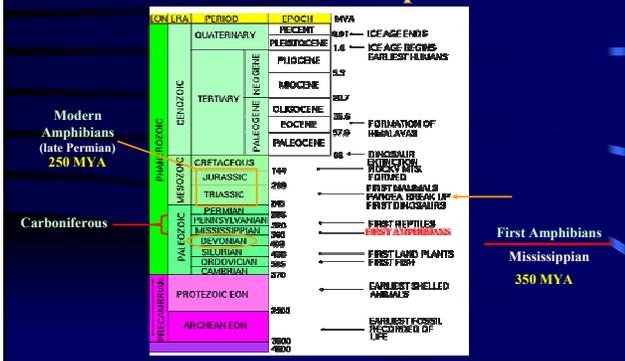
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# Fossil Record of Amphibians




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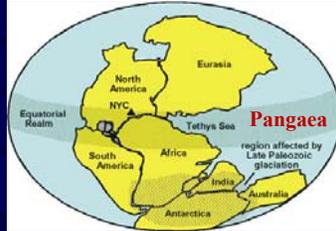
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## Evolutionary transitions

First tetrapods appeared in the Devonian (400 MYA)

Tropical/subtropical latitudes  
Primitive plants and arthropods



Why did fish emerge on land?

1. Find food or evade predators
2. Low oxygen levels
3. Periodic droughts

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## Fish to Tetrapods

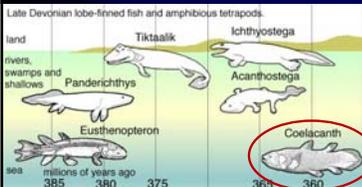
Sarcopterygian (lobe-finned fishes)

### Eusthenopteron

- Pelagic
- Internal nostrils
- Distinct humerus, ulna, and radius and femur, tibia, and fibula

### Panderichthys

- Long snout
- Dorsal eyes
- Reduced median fins



### Tiktaalik

- More developed limbs with wrist and finger bones (body postures)
- Robust rib cage
- Lungs and gills
- Neck separated from body

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## Fish to Tetrapods

Greenland

*Ichthyostega*



- Piscivorous
- Limbs likely used for navigating
- Tail for balance
- Skeletal structure > forelimbs
- Lungs



*Acanthostega*



- Piscivorous
- Fish-like
- Limbs likely used for paddling
- Skeletal structure > Elbow could not bend
- Gills and Lungs
- 8 digits

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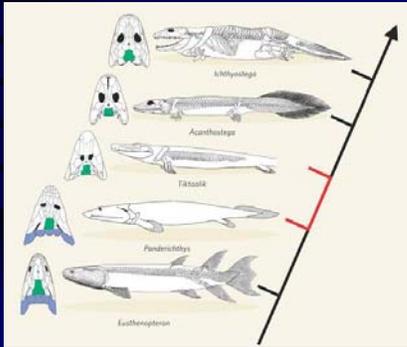
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## Fish to Tetrapods




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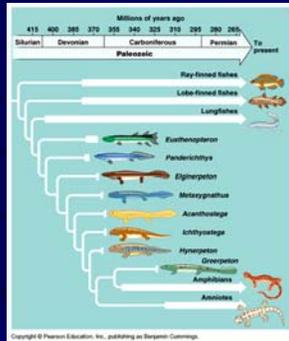
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## Evolutionary Gap

30 million year gap in the fossil record for tetrapods

Relationships between Devonian and Carboniferous tetrapods obscured




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## Temnospondylous Amphibians

Carboniferous and Permian Periods



- 1.5-2 m long
- Bicuspid pedicellate teeth
- Lungs & Cutaneous Respiration
- Likely piscivorous
- Engulfed prey
- Not a strong swimmer or fast tetrapod (likely hunted by stealth or opportunity)
- Shoulder disconnected from skull



*Eryops megacephalus*




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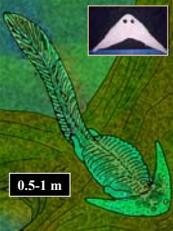
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## Lepospondylous Amphibians

Carboniferous and Permian Periods



**Nectridia**

- Mostly Aquatic
- Resembled Newts (flat tails)
- Some with triangular heads
- Small fish and aquatic invertebrates

**No larval forms known**



**Microsauria**

- “Small Lizard”
- Terrestrial and fossorial



**Lysorophia**

- Elongate body
- Diminutive limbs
- Fenestrated skulls

0.5-1 m

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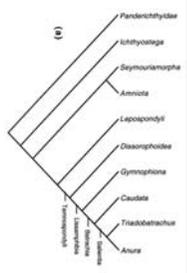
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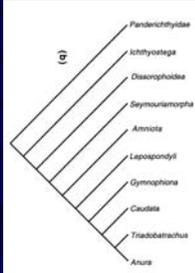
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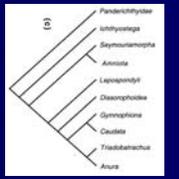
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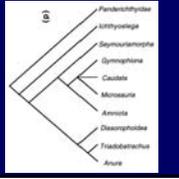
(a)



(b)



(c)



(d)

(Zardoya and Meyer 2001, Laurin 2002)

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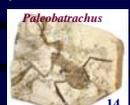
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## Fossil Record of Lissamphibia

Triassic, Jurassic and Cretaceous Periods

**1) Anurans**



*Palaeobatrachus*

**Triadobatrachus massinoti**

- Origin: Madagascar
- Early Triassic (230 mya)



**2) Salamanders**



*Karuauus sharovi*

- Origin: Kazakstan
- Late Jurassic (170 mya)



**3) Caecilians**



*Apodops pricei*

- Origin: Gondwanaland (SA)
- Late Cretaceous (100 mya)



Video

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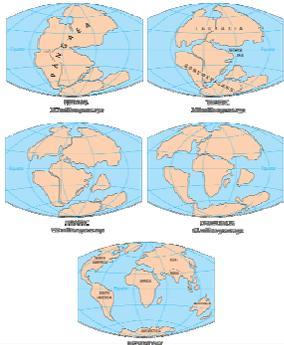
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## Historical Biogeography



Alfred Wegener  
Continental drift

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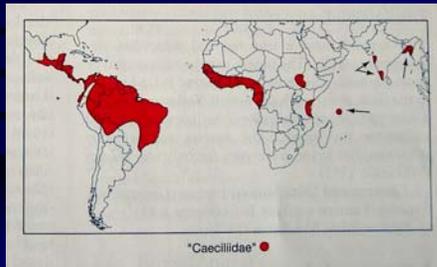
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## Historical Biogeography

### Continental drift and Caecilians



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## Lecture summary

- General characteristics of amphibians
- Characteristics of extant amphibian orders
- Diversity of extant amphibian orders
- Evolutionary history of amphibians

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