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.
2) Duellman and Trueb: pp. 424-443

Lecture Structure

I. Class Amphibia Characteristics

II. Extant Amphibia Families

III. Amphibian Fossil Record

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)

Amphibia Characteristics

1) Cutaneous Respiration
- Oxygen and CO_2 Transfer (moist)
- Family Plethodontidae (lungless salamanders)
- Gills (larvae, few adult salamanders), 2 Lungs (adults)


Plethodon dorsalis

2) Two Types of Skin Glands
- Mucous Glands (cutaneous respiration)
- Glanular Glands (toxic secretions)
  - Paratoid Glands

3) Sensory Papillae in Inner Ear and Doubled Transmission Channels in Middle Ear
- Colemulla-basilar Papilla
- Opercular-amphibian Papilla (<1000 Hz)

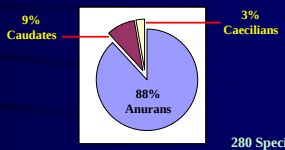
4) Green Rods in Retina (excluding caecilians)
- Function Unknown
- Other Light Receptors: red rods, single and double cones

5) Bicuspid Pedicellate Teeth
- Crown (above gum), Pedicel (connected to jawbone)
- New Crown Emerges from Pedicel

Modern Orders of Amphibia

- Gymnophiona (caecilians)
  - 167 species


Ichthyophis kohtaoensis



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

- Caudata (salamanders)


Plethodon shermani

  - 559 species

- Anura (frogs)
  - 5,420 species


Dendrobates tinctorius

Gymnophiona

Caecus = blind

Characteristics:

- Limbless (pectoral & pelvic girdles absent)
- Degenerate Eyes (most are fossorial)
- Internal Fertilization (phallodeum)
- 20% Viviparous; 80% Oviparous
- Earthworm like (7 cm – 1.5 m)

•Tropical Distribution

•6 Families

Families:

1) **Caeciliidae** (Common Caecilians)

- 95 species (57%)
- Primary Annuli
- Most Fossorial
- No true tail
- Stegokrotaphic Skull

Dermophis mexicanus

2) **Ichthyophiidae** (Fish Caecilians)

- 38 species (23%)
- Primary Annuli w/ Secondary & Tertiary
- True tail
- Stegokrotaphic Skull

Ichthyophis kohtaoensis

Gymnophiona

Families:

3) **Typhlonectidae** (Aquatic Caecilians)

- 14 species (8%)
- Primary Annuli
- No true tail
- Zygokrotaphic Skull
- Strongly Aquatic

Chthonerpeton indistinctum

4) **Rhinatrematidae** (Beaked Caecilians)

- 9 species (5%)
- Primary Annuli w/ Secondary & Tertiary Grooves
- True tail
- Zygokrotaphic Skull

Most Primitive

5) **Scolecomorphidae** (Tropical Caecilians)

- 6 species (4%)
- Primary Annuli
- No true tail
- Zygokrotaphic Skull
- Vestigial scales in the most posterior annuli

Scolecomorphus vittatus

6) **Uraeotyphlidae** (Indian Caecilians)

- 5 species (3%)
- Primary Annuli w/ Secondary Grooves
- True tail
- Stegokrotaphic Skull

Uraeotyphlus

Caudata

•Smokeys Diversity (31)

Characteristics:

- Tailed Amphibians
- Well-developed limbs (except aquatic)
- Internal Fertilization (most)
- Larval Development External (most)
- Lizard like (30 mm – 1.5 m)
- Lack Tympanum & Middle Ear (opercular)

•Mostly Temperate Distribution

•10 Families

Families:

1) **Plethodontidae** (Lungless Salamanders)

- 378 species (68%)
- U.S. & Neo-tropics
- Cutaneous respiration
- Nasolabial groove (chemoreception)
- Reduced skull
- Eggs usually guarded

Plethodon shermani

2) **Salamandridae** (True Salamanders)

- 74 species (13%)
- U.S., Europe, SE Asia
- Lungs
- Skin toxic and brightly colored
- Free-swimming larvae (most)

Salamandra algira

Caudata

Families:

3) Hynobiidae (Asian Salamanders)

- 51 species (9%)
- Asia
- Lack of courtship (males deposit sperm)
- Free-swimming larvae
- Teeth are in patches

Hynobius chinensis

4) Ambystomatidae (Mole Salamanders)

- 32 species (6%)
- North America
- Highly Terrestrial (most)
- Primarily Winter Breeders
- Aquatic courtship
- Free-swimming larvae

Ambystoma tigrinum

5) Proteidae (Mudpuppies & Waterdogs)

- 6 species (1%)
- Eastern US & Europe
- Obligate Paedomorphic
- Depressed body, external gills
- *Necturus* prefer crawfish

Necturus maculosus

6) Sirenidae (Sirens)

- 4 species (0.7%)
- Southern US
- Obligate Paedomorphic
- External Fertilization (likely)
- Pre-maxillary beak

Siren intermedia

Caudata

Families:

7) Rhyacotritonidae (Torrent Salamanders)

- 4 species (0.7%)
- Coastal Pacific NW
- Semi-aquatic
- No operculum
- Reduced Lungs
- Bright yellow abdomen

Rhyacotriton kezeri

8) Dicamptodontidae (Giant Salamanders)

- 4 species (0.7%)
- Coastal NW and Canada
- Large living terrestrial salamanders (20 cm SVL)
- Vomerine Teeth (M)
- Larvae develop 2-5 yrs

Dicamptodon ensatus

9) Amphiumidae (Amphiumas)

- 3 species (0.5%)
- SE United States
- Obligate Paedomorphic
- No external gills, gill slits
- Spermatophore Directly Deposited into Spermatheca
- Number of Toes

Amphiuma tridactylum

10) Cryptobranchidae (Hellbenders)

- 3 species (0.5%)
- Eastern U.S. & China
- Obligate Paedomorphic
- No external gills, gill slits
- Excessive skin (respiration)
- External Fertilization
- Largest Salamanders in the World (most primitive)

Cryptobranchus alleganiensis

Anura

Characteristics:

Saltatorial 2-10X BL

- Shortened Presacral Vertebrate (usually 8)
- Ribs are reduced or absent (2nd or 4th)
- Presacral Vertebrae Firmly Articulated
- Large Hind Limbs, No tail (except 1 family)

Video

- External Fertilization (usually)
- Flat heads and Large Mouths (usually)
- Vocal Sacs in Males (usually)

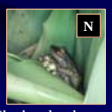
- Global Distribution

- 29 Families

Families:

1) Leptodactylidae (Southern Frogs)

- 1283 species (24%)
- Neo-tropics & subtropics
- Male broods eggs
- *E. jasperi* is viviparious (all other direct dev)
- Hawaii



Eleutherodactylus coqui

2) Hylidae (Tree Frogs)

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

Agalychnis callidryas

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"

Rhacophorus reinwardtii

Anura

Families:

7) Hyperoliidae (African Tree Frogs)

- •261 species (4.8%)
- •Africa, Madagascar, Seychelles
- •Pupil vertically elliptical
- •Toe disks
- •Reed and Sedge Frogs

Leptopelis vermiculatus

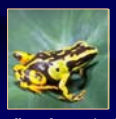
8) Dendrobatidae (Poison Arrow Frogs)

- •252 species (4.7%)
- •Central & South America
- •Brightly colored, toxic skin
- •Most very small (<1 inch)
- •Males wrestle for dominance
- •Tadpoles ride on males back

Dendrobates tinctorius

9) Mantellidae (Mantellas)

- •165 species (3%)
- •Madagascar only
- •Brightly colored, toxic skin
- •Most very small (<1 inch)
- •Converged Evolutionarily with Dendrobatidae



Mantella madagascariensis

10) Centrolenidae (Glass Frogs)

- •143 species (2.6%)
- •Central & South America
- •Transparent Skin (no ribs)
- •Most very small (<1 inch)

- •Eggs guarded by males over stream

Centrolene prosoblepon

Anura

Families:

11) Megophryidae (Cryptic Frogs)

- •138 species (2.5%)
- •Asia & Indonesia
- •Leaf-like Appearance
- •Poor Jumpers
- •Paddle Shaped Tongue
- •Tadpoles: Surface Foragers

Brachytarsophrys carinensis

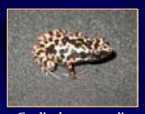
12) Myobatrachidae (Water Frogs)

- •126 species (2.3%)
- •New Guinea, Australia, and Tasmania
- •Foam Nests in Water
- •*Rheobatrachus* (extinct)

Limnodynastes dumerilii

13) Arthroleptidae (Squeakers)

- •51 species (0.9%)
- •Sub-Saharan Africa
- •Previously a part of Ranidae
- •Most lay eggs in water and free-swimming tadpoles



Cardioglossa aureoli

14) Pipidae (Tongueless Frogs)

- •31 species (0.6%)
- •Africa and South America
- •Fully Aquatic Frogs
- •Webbed feet, long fingers with keratinized tips
- •Eyes dorsal and no tongue

Xenopus laevis

Anura

Families:

15) Astylosternidae (Astylosternids)

- 29 species (0.5%)
  - Sub-Saharan Africa
  - Often combined with #13
  - Differ from #13: horizontal pupils & toe discs
  - Hairy Frog

Trichobatrachus robustus

16) Discoglossidae (Disc-tongued frogs)

- 12 species (0.2%)
  - Northern Africa, SW Europe
  - Male carries eggs on hind legs
  - Females vocalize some
  - Toad-like (terrestrial & life in burrows)

Alytes obstetricans

17) Pelobatidae (Spadefoots)

- 11 species (0.2%)
  - United States, Mexico, Europe and Eastern Asia
  - Xeric environments
  - Explosive breeding
  - Fast developing larvae (cannibalistic phenotype)

Scaphiopus couchii

18) Brachycephalidae (Pumpkin Toads)

- 11 species (0.2%)
  - SE Brazil
  - All direct development
  - Most bright orange
  - *B. didactylus*: smallest tetrapod in southern Hemisphere (3/8")

Brachycephalus ephippium

Anura

Families:

19) Bombinatoridae (Fire-bellied Toads & Barbourulas)

- 10 species (0.2%)
  - Europe; Turkey, Russia, China, Korea, Japan
  - 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
  - Prehensile tongue

Hemisus marmoratus

21) Heleophrynidae (Ghost Frogs)

- 6 species (0.1%)
  - Southern Africa
  - Fast-flowing streams
  - Well-developed toe discs, spines (males), 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

Anura

Families:

23) Leiopelmatidae (Leiopelmatids)

- 4 species (0.1%)
  - New Zealand
  - Do not have protusible tongues
  - Do not call
  - Alternating kicks (swim)

Leiopelma archeyi

24) Pelodytidae (Parley Frogs)

- 3 species (0.1%)
  - Black & Caspian Seas, S. Europe
  - Bulging Eyes; Parsley Color
  - Females reported vocalizing when amplexed

Pelodytes punctatus

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 (Mouth-brooding Frogs)

- 2 species (<0.1%)
  - Southern South America (Chile)
  - Tadpoles Develop in Vocal Sac (male)
  - "Rhinoceros nosed"

Rhinoderma darwinii

Anura

Families:

27) Allophrynidae (Ruthven's Frog)

- **1 species (<0.1%)**
- NE South America
- Centrolenidae (related?)
- Little known about its ecology

Allophryne ruthveni

28) Nasikabatrachidae (Purple Frog)

- **1 species (<0.1%)**
- India (discovered 2003)
- Fossorial
- Explosive breeders
- Little known

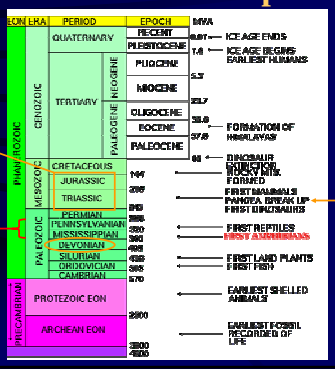
Nasikabatrachus sahyadrensis

29) Rhinophrynidae (Mexican Burrowing Toad)

- **1 species (<0.1%)**
- Costa Rica to Rio Grande
- Fossorial
- Explosive breeders
- Ant-eating specialists
- No teeth

Rhinophrynus dorsalis

Fossil Record of Amphibians



Modern Amphibians (late Permian) **250 MYA**

Carboniferous

First Amphibians

Mississippian Epoch

350 MYA

Lobe-finned or Lungfishes?

Origin of Tetrapods

Lobe-finned Fish (*Osteolepis*)

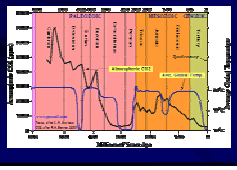
Fin-fold vs. body-spine theories

Lungfish (*Rhipidistia*)

Neoceratodus forsteri

- Freshwater & Marine
- Lungs & Gills
- Ovoviparious
- Dentition, Mouth Parts

Fossil Record (*Ichthyostega*)



- Marine (Freshwater)
- Lungs & Gills
- Similar Skeleton, Lungs, Circulatory System

Labyrinthodont amphibians

Ontogeny & Anatomy (extant)

Fish to Tetrapods

Greenland

Late Devonian Period 360 MYA

Ichthyostega

Acanthostega

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

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

First Tetrapods

Carboniferous and Permian Periods

Labyrinthodontia

- Anthracosauria
  - 1) Embolomeri
  - 2) Seymouridae
- Temnospondyli
  - 1) Trematosauroidea
  - 2) Eryopoidea
  - 3) Dissorophidae

(biphasic) → Lissamphibia (Monophyletic Origin)

Lepospondyli

- Aistopoda

- Nectridea

- Microsauria

Anurans, Salamanders, Caecilians → Lissamphibia (Polyphyletic)

Paedomorphism

Temnospondylous Amphibians

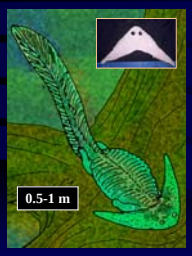
Carboniferous and Permian Periods

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

Eryopus megacephalus

Nectrideans and Microsaurs

Carboniferous and Permian Periods



Diplocaulus magnicornus

Nectridia

- Mostly Aquatic
- Resembled Newts (flat tails)
- Some with triangular heads
- Hydrofoils in slow moving streams
- Small fish and aquatic invertebrates

Jurassic (180 mya)

Microsauria

- "Small Lizard"
- Terrestrial (lizards), aquatic (newts), and fossorial

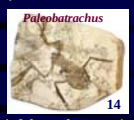
Fossil Record of Lissamphibia

Triassic, Jurassic and Cretaceous Periods

Probably Triassic for All Orders

Video

1) Anurans



What are the most primitive families?

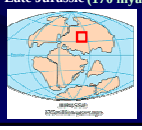
Triadobatrachus massinoti

- Origin: Madagascar
- Early Triassic (230 mya)

2) Salamanders

Karuaus sharovi

- Origin: Kazakstan
- Late Jurassic (170 mya)



3) Caecilians

Apodops pricei

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