The diversity and evolution of Amphibia:

Lecture goal
To familiarize students with characteristics of the Class Amphibia and the diversity of extant amphibians.

Required readings:

Supplemental readings:
Wells: pp. 16-41, 59-65, 75-77

http://amphibiaweb.org/sw/index.html

Lecture roadmap
Characteristics of amphibians
Extant amphibian orders
Characteristics of amphibian orders and diversity
What are amphibians?

These foul and loathsome animals are abhorrent because of their cold body, pale color, cartilaginous skeleton, filthy skin, fierce aspect, calculating eye, offensive smell, harsh voice, squalid habituation, and terrible venom; and so their Creator has not exerted his powers to make many of them.

Carl von Linne (Linnaeus)
Systema Naturae (1758)

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 CO₂ 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)
   - Parotid Glands
   - Other glands (not in all species)
     - Nuptial
     - Wax
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 basilaris (>1000 Hz)
- Papilla amphibiorum (≤1000 Hz)

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 controls 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)

Modern Orders of Amphibia

1. Gymnophiona (caecilians)
   + 181 species

2. Caudata (salamanders)
   + 584 species

3. Anura (frogs)
   + 5,843 species

Modern Orders of Amphibia

1. Gymnophiona (caecilians)
   + 181 species
   - 8% Caudata
   - 2% Caecilians
   - 90% Anurans

2. Caudata (salamanders)
   + 584 species
   - 280 Species in U.S.
   (86 Species in TN)

3. Anura (frogs)
   + 5,843 species
   - Dendrobates tinctorius
   - Plethodon shermani
   - Ichthyophis kohtaoensis
Gymnophiona (Caecilians)

Characteristics:
- Limbless (pectoral & pelvic girdles absent)
- Elongate and annulated bodies
- Degenerate Eyes (covered with skin or bone)
- Internal Fertilization (phallodeum)
- Tentacle between eye and nostril
- Left lung reduced or absent
- Some with dermal scales
- Distinct skulls
  - Stegokrotaphic versus Zygokrotaphic

Tropical Distribution

6 Families

Caecilian families

1) Caeciliidae (Common Caecilians)
   - 103 species (57%)
   - Primary Annuli
   - Most fossorial
   - No true tail
   - Stegokrotaphic skull
   - Can reach 5 ft in length

- Boulengerula fischeri
- Boulengerula boulengeri
- Dermophis mexicanus
- Gegeneophis mhadeiensis
- Gegeneophis danieli

Caecilian families

2) Ichthyophiidae (Fish Caecilians)
   - 43 species (23%)
   - Primary annuli with secondary & tertiary annuli
   - True tail
   - Females attend eggs
   - Stegokrotaphic skull
   - Primitive family

- Ichthyophis kohtaoensis
- Ichthyophis kohtaoensis

Primitive family
### Caecilian families

#### 3) Typhlonectidae (Aquatic Caecilians)
- 13 species (8%)
- Primary annuli
- No true tail
- Strongly aquatic
- Zygokrotaphic skull
- Viviparous

#### 4) Rhinatrematidae (Beaked Caecilians)
- 9 species (5%)
- Primary annuli with secondary & tertiary annuli
- True tail
- Oviparous
- Zygokrotaphic skull
- Primitive family

#### 5) Scolecomorphidae (Tropical Caecilians)
- 6 species (4%)
- Primary annuli
- No true tail
- Some are viviparous
- Zygokrotaphic skull
- Calcified spines on phallosdea

#### 6) Uraeotyphlidae (Indian Caecilians)
- 7 species (3%)
- Primary annuli with secondary annuli
- True tail
- Stegokrotaphic skull
Caecilian morphology and ecology

Some other topics to explore on your own

1. Modes of locomotion
   - How does their unique musculoskeletal system impact movement?

2. Burrowing
   - How do the traits of caecilians function for burrowing?

3. Sensory systems
   - How has the life style of caecilians impacted eye development?

Caudata (Salamanders)

Characteristics:
- Tails and superficially segmented bodies
- Well-developed limbs (except aquatic)
- Internal fertilization (most)
- Larval development external (most)
- Pheromones (mucous glands)
- Lack tympanum & middle ear
- Regenerate lost limbs

Mostly Temperate Distribution

10 Families

Salamander families

1) Plethodontidae (Lungless salamanders)
   - 394 species (68%)
   - Found in the US and New World Tropics
   - Cutaneous respiration
   - Nasolabial groove (chemoreception)
   - Reduced skull
   - Eggs usually guarded

Feeding Videos
2) Salamandridae (True salamanders)
- 81 species (13%)
- Found in the US and SE Asia
- Lungs
- Toxic skin with bright coloration
- Free-swimming larvae in most species

Tylototriton shanjing

Triturus pygmaeus

Neurergus crocatus

Neurergus kaiseri

Triturus dobrogicus

3) Hynobiidae (Asian salamanders)
- 53 species (9%)
- Found in Asia
- External fertilization
- Reduced lungs in most species
- Teeth are in patches

Hynobius tsuensis

Batrachuperus pinchonii

Salamandrella keyserlingii

Ranodon sibiricus

Pachyhynobius shangchengensis

Onychodactylus japonicus

4) Ambystomatidae (Mole salamanders)
- 32 species (6%)
- Found in North America
- Highly terrestrial adults
- Primarily winter and spring breeders
- Aquatic courtship
- Hybridization common (Jefferson's and Blue-Spotted)

Ambystoma mavortium

Ambystoma opacum

Ambystoma annulatum

Ambystoma jeffersonianum
Salamander families

5) Proteidae (Mudpuppies and Waterdogs)
- 6 species (1%)
- Found in eastern US and Europe
- Obligate paedomorphs
- Depressed body and external gills
- Cave dwelling species

6) Sirenidae (Sirens)
- 4 species (0.7%)
- Found in southern US (still water)
- Obligate paedomorphs
- External gills
- External fertilization (lack spermatheca)
- Lack pelvic girdles, eye lids, and pedicellate teeth
- Pre-maxillary beak

Lesser Siren - *Siren intermedia*

7) Rhyacotritonidae (Torrent Salamanders)
- 4 species (0.7%)
- Found in coastal NW US
- Semi-aquatic
- No operculum or opercular muscle
- Reduced lungs
- Bright yellow abdomen

8) Dicamptodontidae (Giant Salamanders)
- 4 species (0.7%)
- Found in coastal NW US and Canada
- Large terrestrial salamander (20 cm SVL)
- Vomerine teeth (shape of M)
- Larvae develop for 2-5 years
Salamander families

9) Amphiumidae (Amphiunas)
- 3 species (0.5%)
- Found in SE US
- Obligate paedomorphs
- No external gills or gill slits
- Spermatophore directly deposited into spermatheca
- Toe number used for species ID

Three-toed amphiuma – Amphiuma tridactylum

Salamander families

10) Cryptobranchidae (Hellbenders)
- 3 species (0.5%)
- Found in eastern US, China & Japan
- Obligate paedomorphs
- No external gills, excessive skin folds
- External fertilization
- No eye lids or tongue pad

Feeding Videos
Some other topics to explore on your own

1. Adaptations
   - How have salamanders adapted to climbing?
2. Paedomorphosis
   - What traits are associated with paedomorphosis?
3. Evolution of lunglessness
   - What potential selective forces have led to lunglessness?

**Anura (Frogs and Toad)**

**Characteristics:**
- Shortened presacral vertebrae (usually 8)
- Ribs are reduced or absent (2nd or 4th)
- 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)

**Groups:**
- Archaeobatrachia (4 families)
- Mesobatrachia (5 families)
- Neobatrachia (all other families)

**Global Distribution**
- 29 Families

**Anuran families**

1. Leptodactylidae (Southern Frogs)
   - 1283 species (24%)
   - Found in the New World Tropics
   - Males brood eggs
   - Foam nests
   - Varied life history (tadpoles, direct dev., viviparous)
   - Eggs usually guarded

- Eleutherodactylus coqui
  - Varied life history (tadpoles, direct dev., viviparous)
  - Eggs usually guarded

- Lithodytes lineatus

- Leptodactylus mystacinus

- Pleurodema thaul

- Ceratophrys ornata

- Telmatobius culeus
2) **Hylidae (Tree Frogs)**
- 835 species (15%)
- Global distribution
- Toe discs
- Good climbers and jumpers
- Free swimming tadpoles (most)

- *Anotheca spinosa*
- *Cruziohyla calcarifer*
- *Dendropsophus berthaultae*
- *Hylomantis lemur*
- *Pachymedusa dacnicolor*
- *Triprion petasatus*
- *Scinax garbei*

3) **Ranidae (True Frogs)**
- 799 species (14.7%)
- Global distribution (Africa and Asia most)
- Well-developed legs and webbed feet
- Free swimming tadpoles (most)

- *Pyxicephalus adspersus*
- *Ceratobatrachus guentheri*
- *Micrixalus saxicola*
- *Tomopterna tuberculosa*
- *Staurois natator*
- *Rana warszewitschii*
- *Platymantis vitiensis*

4) **Bufonidae (True Toads)**
- 493 species (9%)
- Global distribution (Genus *Bufo* for most)
- Cutaneous glands
- Teeth nearly absent
- Bidder’s organ (rudimentary ovary on testes)

- *Nectophrynoides asperginis*
- *Melanophryniscus stelzneri*
- *Atelopus cruciger*
- *Pedostibes hosii*
- *Crepidophryne chompipe*
- *Bufo superciliaris*
Anuran families

5) Microhylidae (Narrow-mouthed Frogs)
- 449 species (8%)
- Mostly tropical and subtropical
- 2-3 palatal folds
- Stout hind legs, short snouts, and globose bodies
- Breviceps - males produce secretions to stick to females

Anuran families

6) Rhacophoridae (Asian Tree Frogs)
- 288 species (5%)
- Africa, India, SE Asia
- Hanging foam nests
- “Flying Frogs” (excessive webbing)
- Flash coloration on inner thigh
- Convergent with hylids

Anuran families

7) Hyperoliidae (African Tree Frogs)
- 261 species (4.8%)
- Africa, Madagascar, Seychelles
- Pupil vertically elliptical
- Toe discs
- Brightly colored
- Some fold leaves over eggs
Anuran families
8) Dendrobatidae (Poison Arrow Frogs)
-252 species (4.7%)
-Found in Central and South America
-Brightly colored and toxic skin (Batrachotoxin)

Dendrobates tinctorius
Dendrobates imitator

Phyllobates terribilis

Anuran families
8) Dendrobatidae (Poison Arrow Frogs)
-252 species (4.7%)
-Found in Central and South America
-Brightly colored and toxic skin
-Most very small (<1 inch)
-Males wrestle for dominance
-Tadpole ride on males back

Dendrobates tinctorius

Anuran families
9) Mantellidae (Mantellas)
-164 species (3%)
-Madagascar only
-Brightly colored and toxic skin
-Most very small (<1 inch)
-Some convergent with Dendrobatidae

Mantella baroni
Mantella madagascariensis
Laliostoma labrosum
Anuran families

10) Centrolenidae (Glass Frogs)
- 143 species (2.3%)
- Central and South America
- Transparent skin, no ribs
- Most very small (<1 inch)
- Males guard eggs

11) Megophryidae (Cryptic Frogs)
- 138 species (2.5%)
- Asia & Indonesia (streams)
- Leaf-like appearance
- Nocturnal and poor jumpers
- Tadpoles feed at surface

12) Myobatrachidae (Water Frogs)
- 126 species (2.3%)
- New Guinea, Australia, & Tasmania
- Foam nests in water
- Unique egg brooding (pouch, mouth)
- Lack toe discs
- Rheobatrachus (extinct)

13) Arthrolepidae (Squeakers)
- 51 species (0.9%)
- Sub-Saharan Africa (forests)
- Direct development (some tadpoles)

14) Pipidae (Tongueless Frogs)
- 31 species (0.6%)
- Africa & South America
- Fully aquatic (webbed feet, lateral line system)
- Pipa (eggs embedded on female)
- Xenopus (tadpoles with barbs)
- Eyes dorsal and no tongue

15) Astylosternidae (Astylosternids)
- 29 species (0.5%)
- Sub-Saharan Africa (forests)
- Often grouped with Arthrolepidae
- Toe discs
- Hairy projections
  - “Claws”
Anuran families

16) Discoglossidae (Disc-tongued Frogs)
- 12 species (0.2%)
- SW Europe; Northern Africa
- Females vocalize some
- Toad-like
- Terrestrial and life in burrows

Alytes cisternasii

17) Pelobatidae (Spadefoots)
- 11 species (0.2%)
- US, Mexico, Europe, Eastern Asia
- Xeric environments
- Explosive breeders
- Fast developing larvae

Pelobates cultripes

Discoglossus sardus

18) Brachycephalidae (Pumpkin Toads)
- 11 species (0.2%)
- SE Brazil
- All direct development
- Reduced digits
- Bright orange (tetrodotoxin)
- B. didactylus: smallest tetrapod in southern hemisphere (3/8”)

Brachycephalus nodoterga

Brachycephalus ephippium

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
- Females dig ditch or transport tadpoles
- Lay eggs in burrow

Hemisotus marmoratus

21) Helophrynidae (Ghost Frogs)
- 6 species (0.1%)
- Southern Africa
- Well-developed toe discs, spines, sucker-like oral disk (tadpoles)
- Fast-flowing streams

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

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

25) Ascaphidae (Tailed frogs)
- 2 species (<0.1%)
- NW US, British Columbia
- Most primitive extant family
- Fast moving streams
- Tail: Cloacal Extension
- Internal fertilization

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
Anuran families

27) Allophrynidae
- 1 species (<0.1%)
- NE South America
- Centrolenidae (related?: foot muscle morphology)
- Little known about its ecology

[Image: Allophryne ruthveni (Ruthven's Frog)]

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

[Image: Nasikabatrachus sahyadrensis (Purple Frog)]

29) Rhinophrynidae
- 1 species (<0.1%)
- Costa Rica to Rio Grande
- Fossorial
- Explosive breeders
- Termite and ant specialists
- No teeth

[Image: Rhinophrynus dorsalis (Mexican Burrowing Toad)]

Anuran morphology and ecology

Some other topics to explore on your own

1. Habitat associations of adult anurans
   - Are most frogs strongly associated with water?

2. Body size and ecology of adult anurans
   - How does body size impact habitat associations?
   - What traits are associated with miniaturization of frogs?

3. Adaptations for different life styles
   - What adaptations are associated with different life styles?