Evolution of Amphibians

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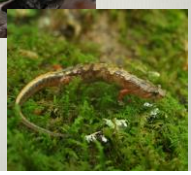
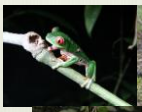
Objectives

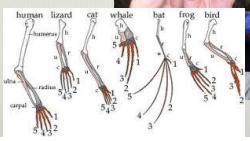
- Define Tetrapod/Amphibian
- Origin of Tetrapods
- Split of Amphibians
- Modern Amphibians
- Extant Families
- Simplification



Tetrapod Characteristics

- Four Limbs
  - Tetra= Four; Pod=Foot
  - Some lost or vestigial
- "One bone→two bones→little blobs→fingers/toes"- Neil Shubin
  - Some lost or vestigial
- Includes all non-fish vertebrates

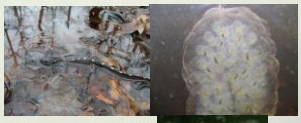


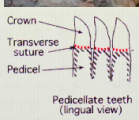


Amphibian Characteristics

"Tetrapod vertebrates that pass through a larval state and undergo metamorphosis into terrestrial adults."

- **Anamniotes**
  - Eggs need moist environment
- **Larval**; metamorphosis
- **Permeable Skin**
  - Cutaneous respiration
- **Two Gland Types**
  - Mucous
  - Poison
- **Pedicellate Teeth**
- **Amphibian papillae/Opercular bone**
  - Can Hear Vibrations
- **Fat Bodies**
- **Green Rods-** fxn unknown
- **Singular Sacrum**
  - Lost in caecilians

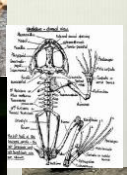


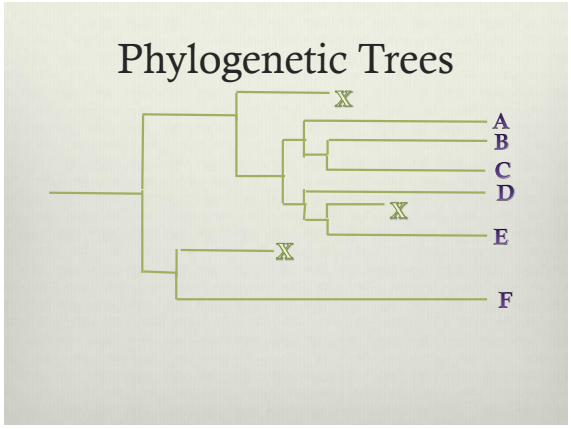


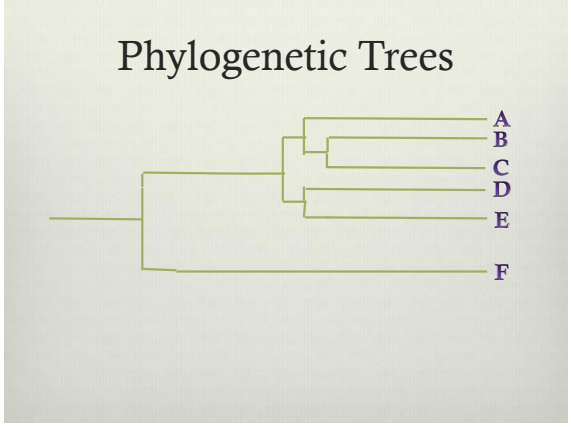
Amphibian Characteristics

As a Fossil…

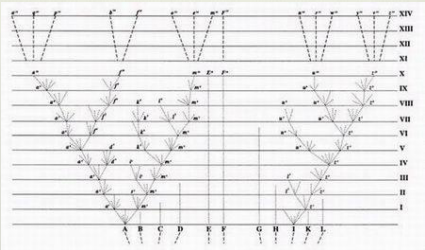
- Articular surface of axis convex
- Exoccipital Bone articulates with dermal roofing
- Hand (Manus) 4 digits
- Foot (Pes) 5 digits
- Some Secondarily Lost
- Important to determine for fossil realtionships



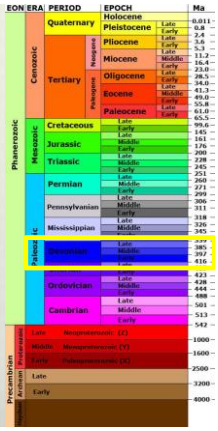

Phylogenetic Trees
X
A
B
C
D
X
E
X
F

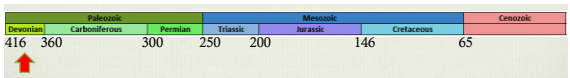

Phylogenetic Trees
A
B
C
D
E
F

Darwin's Tree



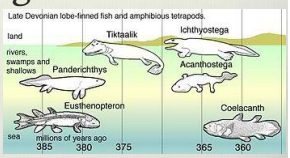
Geologic Time Scale

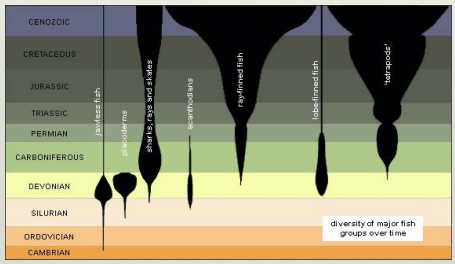




Devonian: Age of Fishes

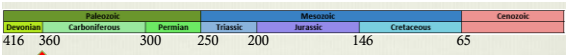
- Lobed-Finned Fishes
  - Lungfishes; Coelacanths
  - Tetrapodomorpha
    - Panderichthyids
      - *Ichthyostega, Acanthostega*
        - **Tetrapods**





Devonian: Fish to Tetrapod

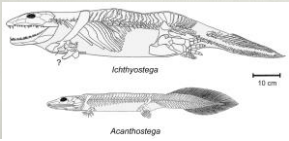
- Panderichthyids 380 mya
  - Predators in shallow water
  - Eyes on top of head
  - Lung and Gills
  - Dorsoventrally Flattened*
  - Pectoral Fins more developed for support/crawling



Devonian: Fish to Tetrapod

- Ichthyostega/Acanthostega 365 mya
  - First tetrapods
  - Still aquatic
  - Ichthyostega maybe seal-like on land

Ichthyostega as pictured in *Scientific American*



Missing Link or "Fishpod": Tiktaalik 375 mya

Paleozoic			Mesozoic			Cenozoic
Devonian	Carboniferous	Permian	Triassic	Jurassic	Cretaceous	

416 360 300 250 200 146 65

Tetrapod Adaptations

Or Exaptations?

Lungs

- Earliest Adaptation

Limbs*

- Movement and support
- Pectorals first

Free movement of head*

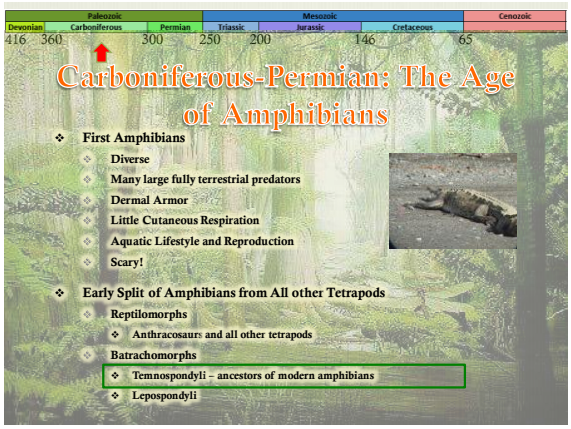
- Functional neck
- Feeding and catching prey

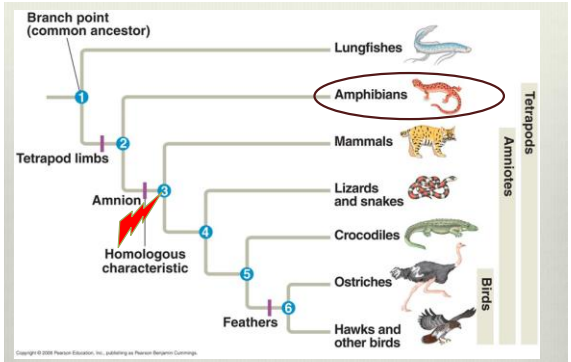
Paleozoic			Mesozoic			Cenozoic
Devonian	Carboniferous	Permian	Triassic	Jurassic	Cretaceous	

416 360 300 250 200 146 65

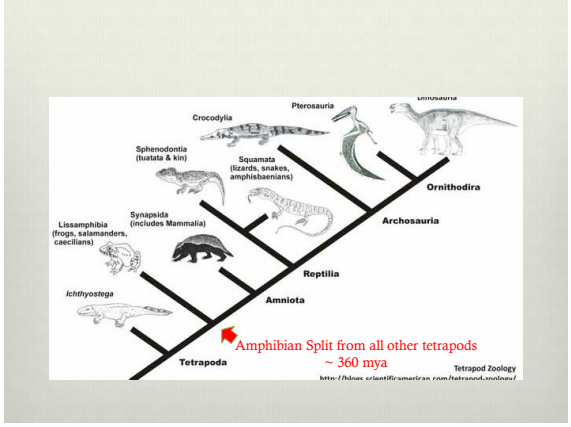
Tetrapod Advantages

- (1) Unexploited resources
- (2) Low Oxygen in warm shallow swamps
- (3) Periodic drought- move between pools

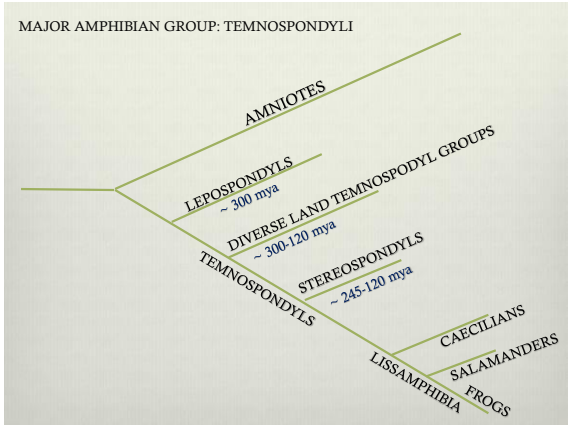


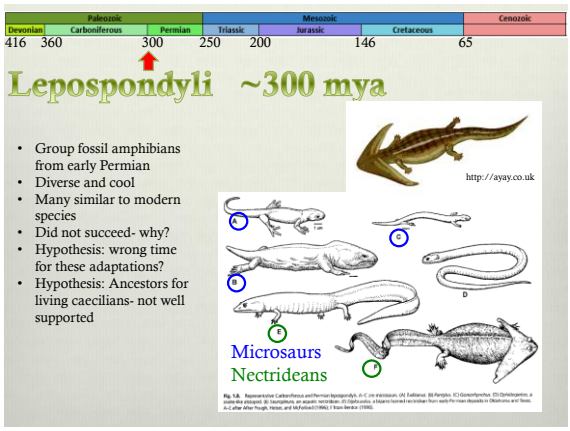


Carboniferous period ~370 MYA. All other tetrapods split from amphibians because of appearance of **amniote eggs**

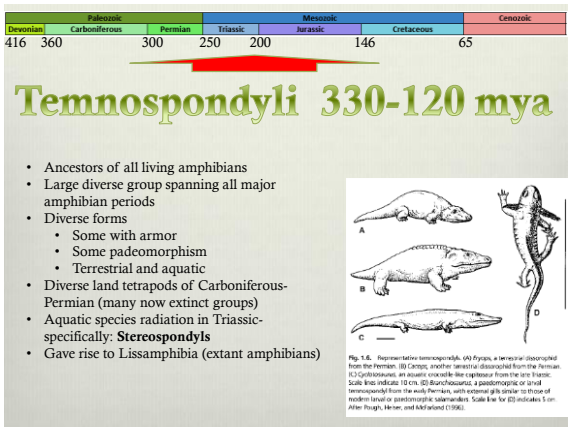


MAJOR AMPHIBIAN GROUP: TEMNOSPONDYLI

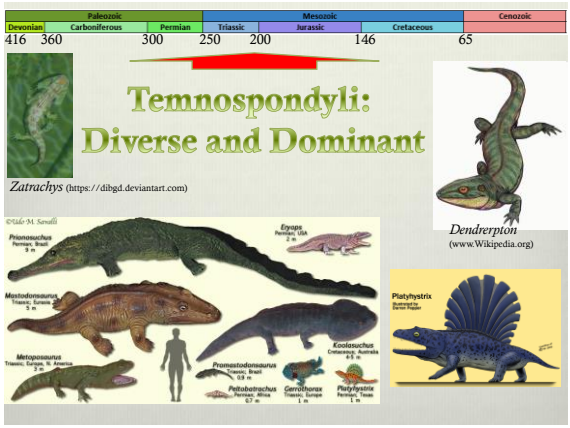


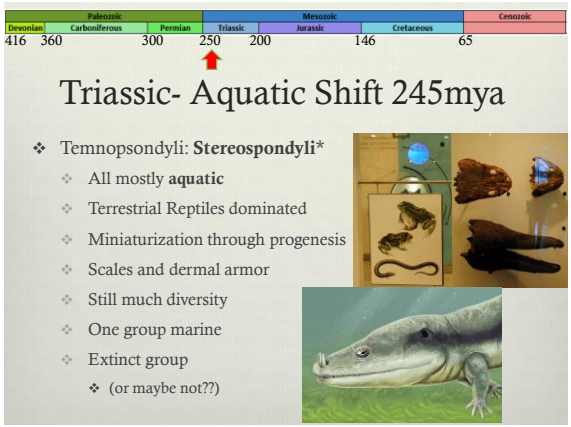


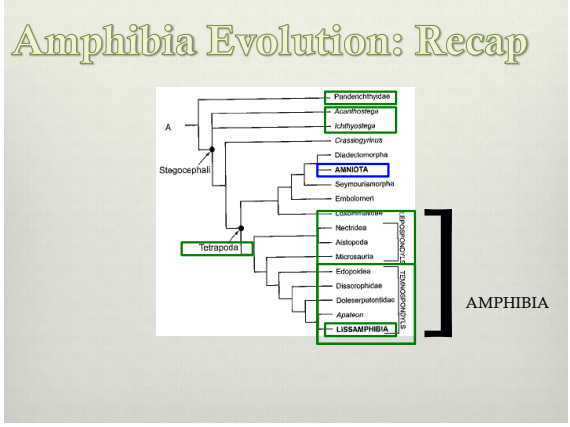
- Group fossil amphibians from early Permian
- Diverse and cool
- Many similar to modern species
- Did not succeed- why?
- Hypothesis: wrong time for these adaptations?
- Hypothesis: Ancestors for living caecilians- not well supported



- Ancestors of all living amphibians
- Large diverse group spanning all major amphibian periods
- Diverse forms
  - Some with armor
  - Some padeomorphism
  - Terrestrial and aquatic
- Diverse land tetrapods of Carboniferous-Permian (many now extinct groups)
- Aquatic species radiation in Triassic- specifically: **Stereospondyls**
- Gave rise to Lissamphibia (extant amphibians)

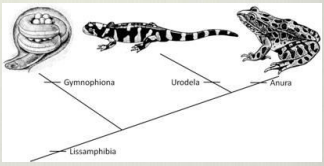

Paleozoic
Mesozoic
Cenozoic
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
416 360 300 250 200 146 65
Temnospondyli:
Diverse and Dominant
Zatrachys (https://dibgd.deviantart.com)
Dendrerpton
(www.Wikipedia.org)
Prionosuchus
Eryops
Mastodonsaurus
Metoposaurus
Koolasuchus
Promastodonsaurus
Peltobatrachus
Gerrothorax
Platyhystrix
Platyhystrix


Paleozoic
Mesozoic
Cenozoic
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
416 360 300 250 200 146 65
Triassic- Aquatic Shift 245mya
Temnopsondyli: Stereospondyli*
All mostly aquatic
Terrestrial Reptiles dominated
Miniaturization through progenesis
Scales and dermal armor
Still much diversity
One group marine
Extinct group
(or maybe not??)


Amphibia Evolution: Recap
Panderichthyidae
Acanthostega
Ichthyostega
A
Crassigyrinus
Stegocephali
Diadectomorpha
AMNIOTA
Seymouriamorpha
Embolomeri
Nectridea
Aistopoda
Microsauria
Tetrapoda
STEGOCEPHALI
Edopoidea
Dissorophidae
Doleserpetontidae
Apateon
LISSAMPHIBIA
TEMNOSPONDYLI
AMPHIBIA

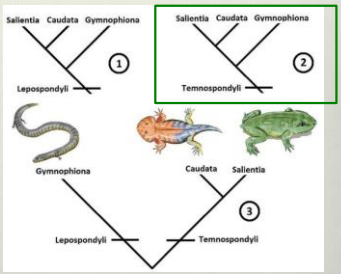
Lissamphibia: Modern Amphibians*

- Class: Amphibia
  - Monophyletic (most likely)
  - Caecilians
  - Frogs
  - Salamanders
- First Appearance
  - *Triadobatrachus* (Frog) 245mya



Lissamphibia: contentious relationships

- Class: Amphibia
  - Monophyletic (most likely)
  - Temnospondyls



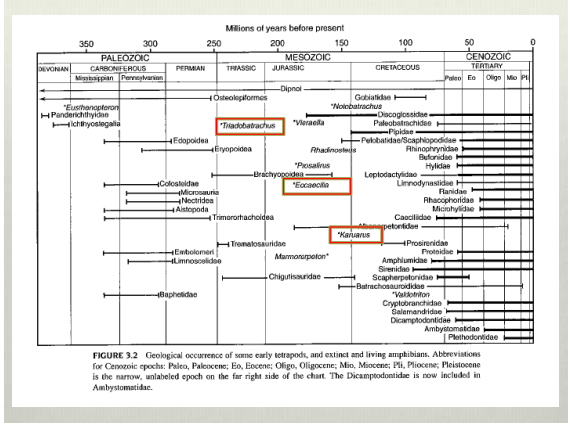
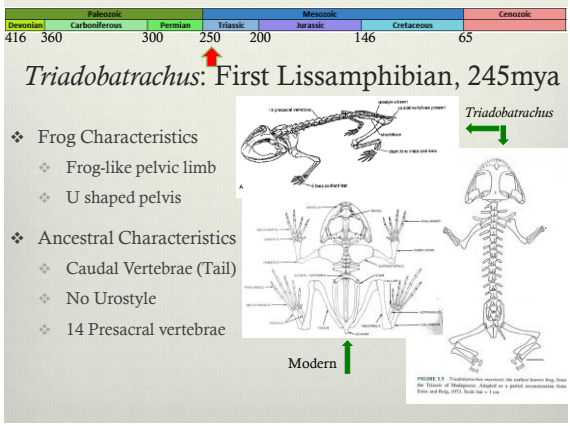
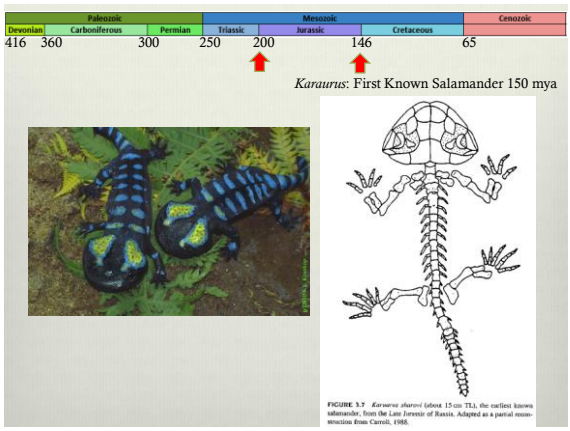
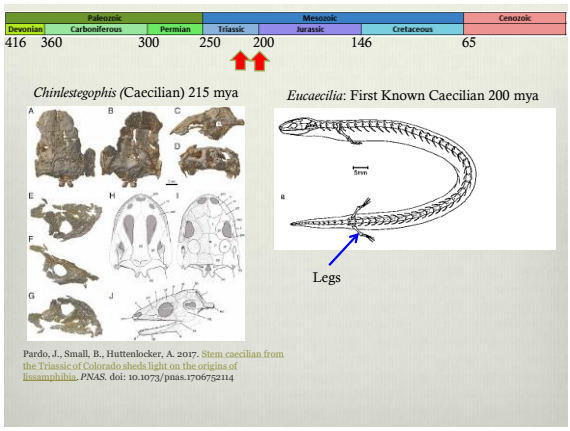
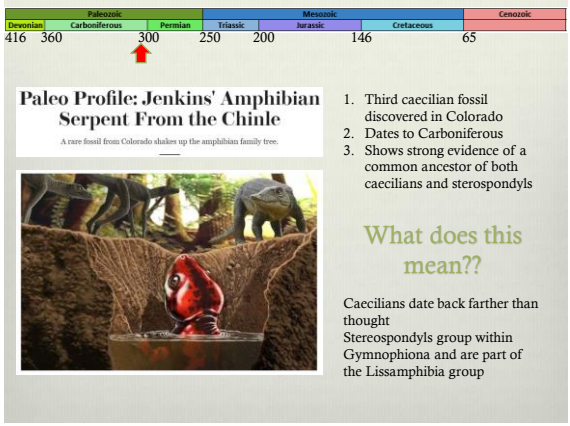


FIGURE 3.2 Geological occurrence of some early tetrapods, and extinct and living amphibians. Abbreviations for Cenozoic epochs: Paleo, Paleocene; Eo, Eocene; Oligo, Oligocene; Mio, Miocene; Pli, Pliocene; Pleistocene is the narrow, unlabeled epoch on the far right side of the chart. The Dicamptodontidae is now included in Ambystomatidae.


Paleozoic
Mesozoic
Cenozoic
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
416 360 300 250 200 146 65
Triadobatrachus: First Lissamphibian, 245mya
Frog Characteristics
Frog-like pelvic limb
U shaped pelvis
Ancestral Characteristics
Caudal Vertebrae (Tail)
No Urostyle
14 Presacral vertebrae
Triadobatrachus
Modern


Paleozoic
Mesozoic
Cenozoic
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
416 360 300 250 200 146 65
Karaurus: First Known Salamander 150 mya

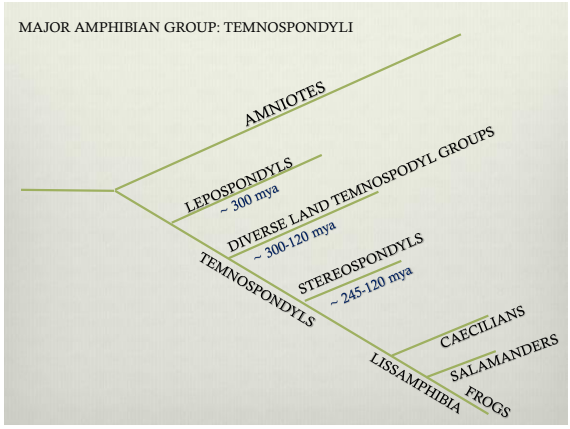

Paleozoic
Mesozoic
Cenozoic
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
416 360 300 250 200 146 65
Chinlestegophis (Caecilian) 215 mya
Eucaecilia: First Known Caecilian 200 mya
Legs
Pardo, J., Small, B., Huttenlocker, A. 2017. Stem caecilian from the Triassic of Colorado sheds light on the origins of lissamphibia. PNAS. doi: 10.1073/pnas.1706752114

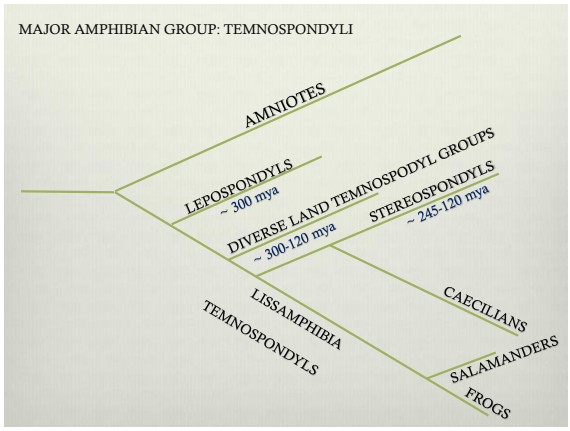


1. Third caecilian fossil discovered in Colorado
2. Dates to Carboniferous
3. Shows strong evidence of a common ancestor of both caecilians and sterospondyls

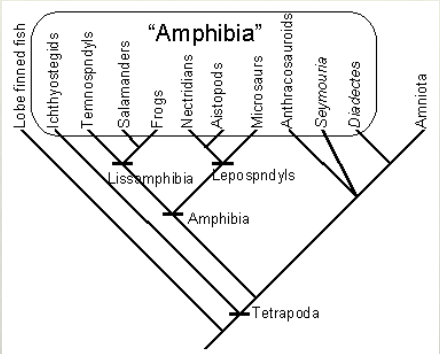
What does this mean??

Caecilians date back farther than thought
Stereospondyls group within Gymnophiona and are part of the Lissamphibia group





MAJOR AMPHIBIAN GROUPS



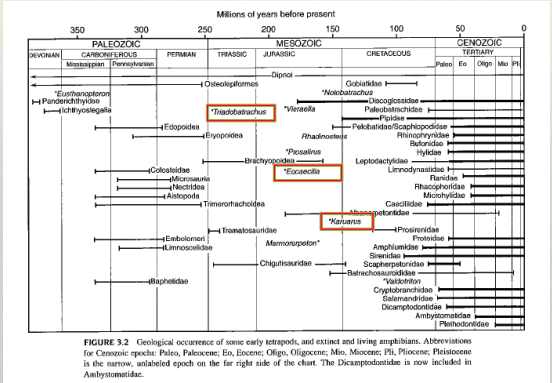


FIGURE 3.2 Geological occurrence of some early tetrapods, and extinct and living amphibians. Abbreviations for Cenozoic epochs: Paleo, Paleocene; Eo, Eocene; Oligo, Oligocene; Mio, Miocene; Pli, Pliocene; Pleistocene is the narrow, unlabeled epoch on the far right side of the chart. The Dicamptodontidae is now included in Ambystomatidae.

Recap

- What period is considered "age of the fishes"

Recap

- Which specimen linked the fish-like limb with a weight-bearing limb?

Recap

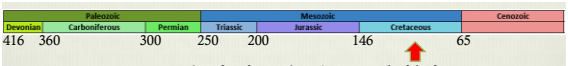
- Which of the following is the first known Lissamphibian?
- A. *Triadobatrachus*
- B. *Eucaecila*
- C. *Karaurus*

Which of the following groups include modern amphibians?

- Lepospondylii
- Ceolacanths
- Temnospondylii
- Nectrideans

- Which vertebrates are not considered tetrapods?
- Which are?

- True or False: Weight- bearing limb development was a result of selective pressure for animals to live on land during drought.



Extant (Living) Amphibians

Anura (frogs and toads)
families: 55
genera: 447
species: 6881

Gymnophiona (caecilians)
families: 10
genera: 33
species: 207

Caudata (salamanders)
families: 10
genera: 68
species: 710

The total number of amphibian species is currently ~~7,087 (Jan 16, 2013)~~

The total number of amphibian species is currently ~~7,231 (Jan 21, 2014)~~

The total number of amphibian species is currently ~~7,384 (Jan 12, 2015)~~

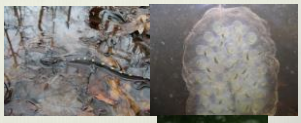
The total number of amphibian species is currently 7,798 (Jan 22, 2018)

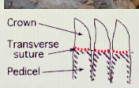
Source: Amphibiaweb.org

Amphibian Characteristics- *Italics only applies to living amphibians*

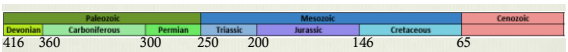
"Tetrapod vertebrates that pass through a larval state and undergo metamorphosis into terrestrial adults."

- **Anamniotes**
  - Eggs need moist environment
- **Larval**; metamorphosis
- ***Permeable Skin***
  - Cutaneous respiration
- **Two Gland Types**
  - Mucous
  - Poison
- **Pedicellate Teeth**
- **Amphibian papillae/Opercular bone**
  - Can hear low frequencies
- ***Fat Bodies***
- ***Green Rods***- fxn unknown
- **Singular Sacrum**
  - Lost in caecilians



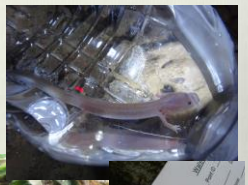


Pedicellate teeth (lingual view)



Evolved Simplifications

- Pronounced in Salamanders
- Paedomorphosis
- Reduction Body Size
- Large Genomes and Cells
- Low Metabolic Rates
  - Affect life history strategies
- Simplified Organ Systems



Anura

Characteristics:

Saltatorial
- •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)

•External Fertilization (usually)

•Flat heads and Large Mouths (usually)

•Vocal Sacs in Males (usually)

•Global Distribution

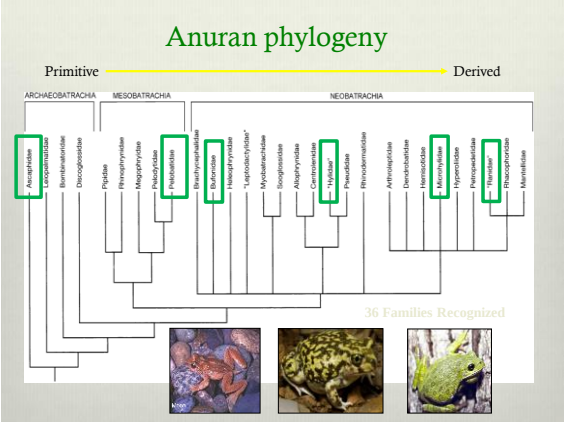
•55 Families!!

Centrolene prosoblepon

Oophaga sylvatica

Hypsiboas rosenbergi

Scaphiopus holbrooki



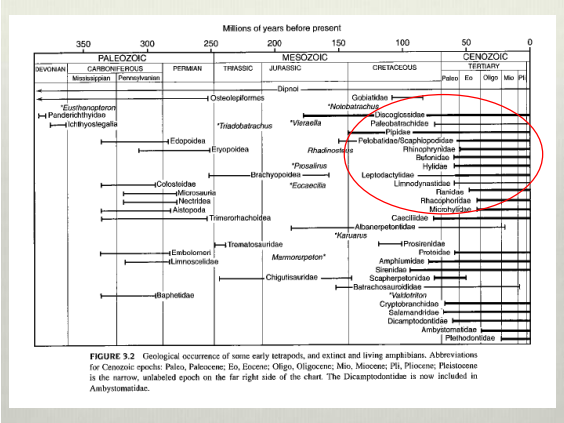


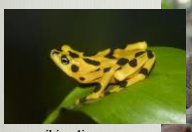
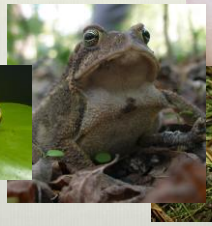
FIGURE 3.2 Geological occurrence of some early tetrapods, and extinct and living amphibians. Abbreviations for Cenozoic epochs: Paleo, Paleocene; Eo, Eocene; Oligo, Oligocene; Mio, Miocene; Pli, Pliocene; Pleistocene is the narrow, unlabeled epoch on the far right side of the chart. The Dicamptodontidae is now included in Ambystomatidae.

Ascaphidae (2 sp)
- Tailed frogs
- Appendage for copulation
- Pac NW only
- *Ascaphus*

Microhylidae (687 sp)
Diverse strategies
New and Old World
- *Gastrophryne* (Americas)
- *Cophixalus* (Australia)
- *Dyscophus* (Madagascar)

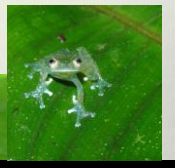


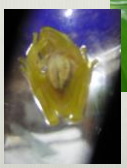
Bufonidae (607)
New and Old world
- True Toads
- Cosmopolitan except Australia/New Zealand
- *Bufo/Anaxyrus*
- *Rhinella marina*
- *Atelopus*- Harlequin Frogs
- Often toxic secretions, and thick glandular skin


www.wikipedia.org

Centrolenidae (153)
New World Only
- Glass Frogs
- Digit 1 points inward
- T-shaped terminal phalanges
- Transparent venter
- Tropical stream breeding
- Dense capillaries in tadpoles= red appearance
- Arboreal

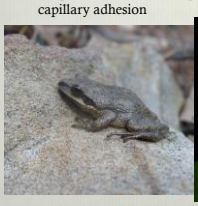


Hylidae (900+ sp)

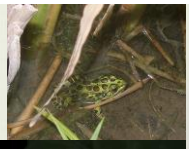
- *Hyla* new world
- *Hypsiboas*
- *Osteocephalus*
- *Scinax*
- *Pseudacris*
- *Phyllomedusa*
- *Litoria* old world
- Many Others
- Arboreal
- Toepads with columnar epithelial cells= good capillary adhesion






Ranidae (300+)

- Cosmopolitan Distribution
- Conraua goliath: Goliath Frog
  - 300 SVL; world's largest frog
- Rhacophorines
  - flying frogs etc
  - Intercalary Cartilage (like hylids)
  - May be own family- NOW ARE
- Mantellas (now mantellidae)
  - Madagascar "poison dart frogs"
- Rana and Lithobates





www.dendrogrove.com

Strabomantidae (687 sp)

- New world only
- *Pristimantis*: 515 species!!- most speciose vertebrate genus!
- All direct development
- "rain frogs"
- Triangular terminal phalanges



Scaphiopodidae (New and Old) + Pelobatidae (Old World Only)
Spadefoots
Europe and NA
Fossorial
- *Scaphiopus*
- *Spea*
- *Pelobates*

Gymnophiona

Caecus = blind

Characteristics:

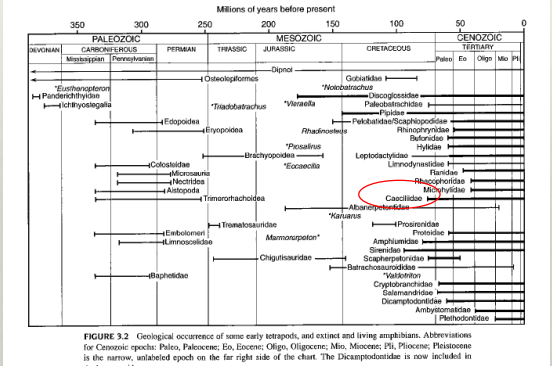
- Earthworm like (7 cm – 1.5 m)
- Limbless (pectoral & pelvic girdles absent)
- Degenerate Eyes (most are fossorial)
- Internal Fertilization (phallodeum)
- 20% Viviparous; 80% Oviparous

•Tropical Distribution

• 10 Families

Uraeotyphlus

Ichthyophis kohtaoensis



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Caudata (Urodela)

•Smokies Diversity (31)

Characteristics:

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

•Mostly Temperate Distribution

•10 Families

Pseudotriton ruber

Ambystoma talpoideum

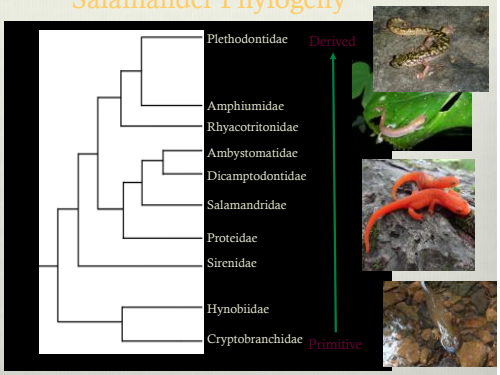
Amphiuma tridactylum

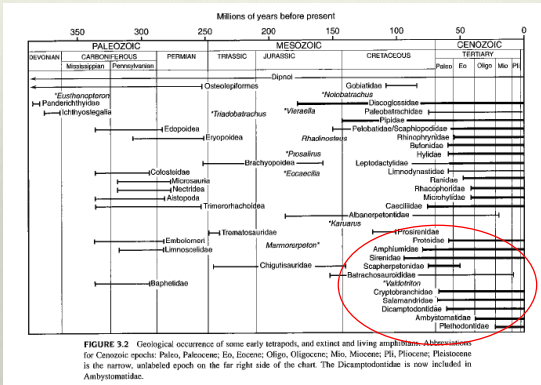
Andrias japonicus

?

?

Salamander Phylogeny





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Salamander vs Lizard

Moist Skin
Toe tips
Rounder head
More dorsoventrally compressed

Epidermal Scales
Ear holes
Claws
Usually body held up over ground