**Topic 4: The Origin of Tetrapods**

- Next two lectures will deal with:
  - Origin of Tetrapods, transition from water to land.
  - Origin of Amniotes, transition to dry habitats.

**The geological time scale**

- Organizes the history of the earth
- Based on geological and biological/fossil criteria
- Allows us to consider "________________"
- Time scale over which geological and ________________ phenomena occur
- Organized into hierarchical ________________, ________________, ________________, and ________________

**The Paleozoic Era**

<table>
<thead>
<tr>
<th>Period</th>
<th>MYA</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permian</td>
<td>245-286</td>
<td>1st</td>
</tr>
<tr>
<td>Carboniferous</td>
<td>286-320</td>
<td>1st reptiles, amphibians specialize</td>
</tr>
<tr>
<td>Devonian</td>
<td>360-408</td>
<td>1st amphibians</td>
</tr>
<tr>
<td>Silurian</td>
<td>408-438</td>
<td>1st jawed fishes</td>
</tr>
<tr>
<td>Ordovician</td>
<td>438-505</td>
<td>1st jawless fishes &amp; land plants</td>
</tr>
<tr>
<td>Cambrian</td>
<td>505-570</td>
<td>1st vertebrates</td>
</tr>
</tbody>
</table>

**The Mesozoic Era**

<table>
<thead>
<tr>
<th>Period</th>
<th>MYA</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretaceous</td>
<td>65-144</td>
<td>- Mass extinction at end of Cretaceous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 1st modern Squamata</td>
</tr>
<tr>
<td>Jurassic</td>
<td>144-208</td>
<td>- 1st Urodela, Anura</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 1st Rynchocephalia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- High reptile diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 1st birds</td>
</tr>
<tr>
<td>Triassic</td>
<td>208-245</td>
<td>1st Angiosperms, dinosaurs, mammals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1st Testudines, ___________________________</td>
</tr>
</tbody>
</table>
The Cenozoic Era

<table>
<thead>
<tr>
<th>Period</th>
<th>Epoch</th>
<th>MYA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Holocene</td>
<td>Recent</td>
<td>Modern humans</td>
</tr>
<tr>
<td></td>
<td>Pleistocene</td>
<td>0.01-1.5</td>
<td>Evolution of humans</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Pliocene</td>
<td>1.5-5</td>
<td>1° hominines</td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td>5-24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oligocene</td>
<td>24-37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eocene</td>
<td>37-58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paleocene</td>
<td>58-65</td>
<td>- 1° Gymnophiona - 1° pacental mammals</td>
</tr>
</tbody>
</table>

What are stem and crown groups?

- Stem groups: Are also monophyletic
- Contain all extant taxa
- Contain all extant & extinct taxa

What are outgroups of Actinopterygii (6)?
- Tetrapoda (3)?
- Actinistia (7)
- Dipnoi (8)

Where do herps fit into the vertebrate phylogeny?

- Lobe-finned fishes
- Contain Actinistia (7), Dipnoi (8), Tetrapoda (3)
- Fins/lims supported by bone and contain muscle
- Teeth have enamel
- What kind of characters are these?

Sarcopterygian lineages

- Coelacanth, Latimeria
- 2 extant species
- Symmetrical, 3-lobed
- "living fossil"

- Lung fishes
- 3 extant genera
- Gondwanan distribution
- 1 in S. America, 1 in Africa, 1 in Australia

Pough et al 2004, Fig 2-1

Benton Fig 9.11

Vertebrate Life Fig 8-35
Sarcopterygian lineages

- Tetrapoda
  - Includes all modern amphibians and amniotes, and their last common ancestor.
  - Fully developed girdle
  - Pectoral girdle free from the skull (not the case in non-tetrapods)
  - Discrete shaft of

Where do herps fit into the vertebrate phylogeny?

- This phylogeny includes only extant taxa
- Many species of early tetrapods and stegocephalians are extinct
- Therefore, must look at both stem and crown Amphibia

Stem and Crown Amphibia

Most groups of Amphibians and all early tetrapods are...
Early tetrapod relationships are contentious…

How do these two hypotheses differ? How are they the same? Why might we prefer one over the other?

Traditional hypothesis
Inclusion of only some taxa, assumption of Temnospondyl-Lissamphibian association

Laurin & Reisz 1997
No a priori assumptions, many more taxa included
Pough et al. 2004 Fig 2-8
What are the evolutionary origins of tetrapods?

- Laurin & Reisz 1997
  - Lepospondyls are:
    - Sister to Lissamphibia
  - Amniotes (including reptiles) are:
    - Sister group to Lissamphibia + Lepospondyls

- Stegocephali
- Tetrapoda
- Lepospondyls
- Temnospondyls

Stegocephali
Tetrapoda
Lepospondyls
Temnospondyls

Pough et al. 2004 Fig 2-8

What are the evolutionary origins of tetrapods?

- Elpistostegidae (Panderichthys)
  - Outgroup to Stegocephalia but closer than Dipnoi
  - Dorsoventrally ditinctive
  - No dorsal fin, dorsal eyes
  - Tetrapod-like body but with fins
  - Developed frontal bones a synapomorphy with stegocephalia

Stegocephali
Tetrapoda
Lepospondyls
Temnospondyls

Pough et al. 2004 Fig 2-3

What are the evolutionary origins of tetrapods?

- Acanthostega & Ichthyostega
  - 6-8 digits per limb
  - What does this mean for ancestral number of digits?

Stegocephali
Tetrapoda
Lepospondyls
Temnospondyls

Vertebrate Life Fig 10-3

What are the evolutionary origins of tetrapods?

- Amniota
  - We will come back to these
  - Mammals, birds, snakes & lizards, turtles, crocodilians

Stegocephali
Tetrapoda
Lepospondyls
Temnospondyls

Next slide
What are the evolutionary origins of tetrapods?

- **Lepospondyls**
  - Carboniferous & Permian
  - Diverse
  - Microsauria – _________
  - Aisopoda – _________ &
  - Nectridea – _________ &
  - newt-like

What are the evolutionary origins of tetrapods?

- **Lissamphibia**
  - Urodela, Anura, Gymnophiona
  - Extant (Finally)

What changes were involved in the transition from water to land?

- **Obligate Aquatic**
- Terrestrial

What changes were involved in the transition from water to land?

- This transition involved aspects of structure and function associated with:
  - __________
  - __________
  - __________
  - __________
  - __________
  - __________

Photos: KP Bergmann, Pough et al. Fig 3-8
What changes were involved in the transition from water to land?

- **Body support**
  - Moving onto land means coping with
  - In the water, the body is supported by the water, on land by limbs
  - Coping with _______________
    - Small in water
    - Large on land

- **Ground reaction forces**
  - Limb girdles became more ______________ to the vertebral column
  - Allows limbs to become support structures and transfer forces to the axis

- **Locomotion**
  - A switch from _______________
  - Terrestrial locomotion is much harder on the
  - Fin-based swimming is replaced by pushing off a substrate with the limbs
  - Lateral undulation plays a role in both
    - ______________ less of an issue on land

Benton 1997 pg 183; Benton Fig 4-2a; Pough et al 2004 Fig 2-2

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What changes were involved in the transition from water to land?

**African lungfish**

**Protopterus**

**Transition from water to land?**

- **Ground reaction forces**
  - Pectoral girdle became more ______________ from the head
  - Minimizes forces exerted on skull and brain, increases head

- **Locomotion**
  - **Vertebral morphology becomes more**
  - **Ichnphostega**

- **Zygapophyses limit excessive intervertebral forces,**
  - **Kardong & Zalisko 2002: Fig 5.8c, 5.11b**

Benton 1997 pg 183; Benton Fig 4-2a; Pough et al 2004 Fig 2-2

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What changes were involved in the transition from water to land?

**Ichthyostega**

**Panderichthys**

**Acanthostega**

**Vertebrate Life Fig 10-3**

**What changes were involved in the transition from water to land?**

- **Vertebral morphology becomes more**
  - **Ichthyostega**

- **Zygapophyses limit excessive intervertebral forces,**
  - **Kardong & Zalisko 2002: Fig 5.8c, 5.11b**

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What changes were involved in the transition from water to land?

**Acanthostega Panderichthys & Acanthostega**

**What changes were involved in the transition from water to land?**

- **Locomotion**
  - **Vertebral morphology becomes more**
  - **Ichnphostega**

- **Zygapophyses limit excessive intervertebral forces,**
  - **Kardong & Zalisko 2002: Fig 5.8c, 5.11b**

Kardong & Zalisko 2002: Fig 5.8c, 5.11b
What changes were involved in the transition from water to land?

- **Body shape**
  - Very flattened in Panderichthys
  - Streamlined but dorsoventrally flattened in Panderichthys
  - Allows invasion of shallow water
  - Also dorsal eyes, no dorsal fin
  - Decrease in hydrodynamics in terrestrial forms

- **Respiration**
  - Gills only to gills & lungs to lungs only
  - Both gills and lungs are ancestral because lungs arose from ________
  - Acanthostega still had gills
  - Ventilation increasingly powered by ________ of the

- **Excretion**
  - Trend from excreting ammonia to ________ to ________
  - Ammonia is most toxic but also most water soluble
  - Ammonia is voided quickly through ________
  - Urea and Uric Acid are concentrated and excreted by ________

- **Water balance**
  - Fishes live in excess water
  - Lissamphibia live in moist environments, but more water-_______ ________ ________
  - Mucous glands limit evaporation from an amphibian’s body
  - Lissamphibia have various behaviors and postures that limit water loss

- **Feeding**
  - ________ is prevalent in fishes, impossible on land
  - On land, jaws and the tongue play a more important role