



# **Exploring Transitional Fossils**

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## **Basic Outline**

- Transitional Fossils – Background & Issues
- Five Case Studies of Transitional Fossils
- Conclusions
- Implications of Transitional Fossils
- Discussion Questions



## **What is a Transitional Fossil?**

- The relationship of morphological change to speciation.
- Known transitions between species are rare.
- Gradual change over time leads to transitional species that can trace ancestry.

(Gingerich 1985; Hopson 1987; Rosslenbroich 2009)

# General Transitions Discovered Over Time

- Origins of speciation:
  - Early Amphibians (from fish-like tetrapod)
  - Early Turtles (from turtle-like intermediate)
  - Early *Hominidae* (from *Homo* genus species)



(Prothero 2005; Li *et al.* 2008; Schoch 2009; Tattersall 2009)

## General Transitions continued...

- Fish to Tetrapod transition
- Synapsid to Mammal transition
- Dinosaur to Bird transition
- Whale to Mammal transition




(Prothero 2005; Johanson *et al.* 2007; Luo *et al.* 2007; Braterman and Holbrook 2009; Hutchinson and Allen 2009)



# **General Methods for Study**

- Molecular timescales
  - measure divergence between species and major lineages.
- Composite sequences of fossils
  - dated relative to strata level.
- Phylogenetic trees
  - parsimonious or molecular relationship of lineages.

(Gingerich 1985; Kumar and Hedges 1998; Anderson *et al.* 2008; Teske and Beheregaray 2009)



## **Religious Problems Associated with** **Transitional Fossils:**

- Transitional fossils are used to link categories of species over time.
- Creationists or intelligent design advocates believe:
  - Sharp boundaries separate major taxonomic groups that are created by their sudden appearance
  - Biology cannot be explained by ordinary laws of nature.

(Hopson 1987; Braterman and Holbrook 2009)



## **Further Problems...**

- The Discovery Institute:
  - Justified under Academic Freedom Act.
  - Generates imitation textbook material for promoting creationist agenda.
  - Well-funded by creationist groups.
  - Further deteriorates political situation of science vs. religion debate.

(Brateman and Holbrook 2009)





## Darwinian Problems...

- Establishment of transitional fossils involves advancements in technology.
- Hypothetical missing links deterred by creationists that obsess with Darwinian thinking from Origin of Species (1859).
  - Curve attention back to 19<sup>th</sup> century scientific thought; distract from advancements developed since 19<sup>th</sup> century thinking.

(Braterman and Holbrook 2009)



## **Fossil Case Studies**

1. Dipteran genus, *Jurasciophila*
2. Early fish-tetrapod, *Taktaalik roseae*
3. Early dinosaur-bird, *Anchiornis huxleyi*
4. Early mammal-whale, *Indohyus*
5. Primitive land-sea mammal, *Puijila darwini*



## Case Study 1:

### New Dipteran genus (2 species)

- *Jurasciophila curvula* and *Jurasciophila lepida*.
- Found in Inner Magnolia, China from the late Middle Jurassic (~160mya).
- New *Jurasciophila* fossils share transitional characteristics between two known genera of Dipterans:
  - *Mesosciophilina* and *Mesosciophilopsis*

(Li and Ren 2009)



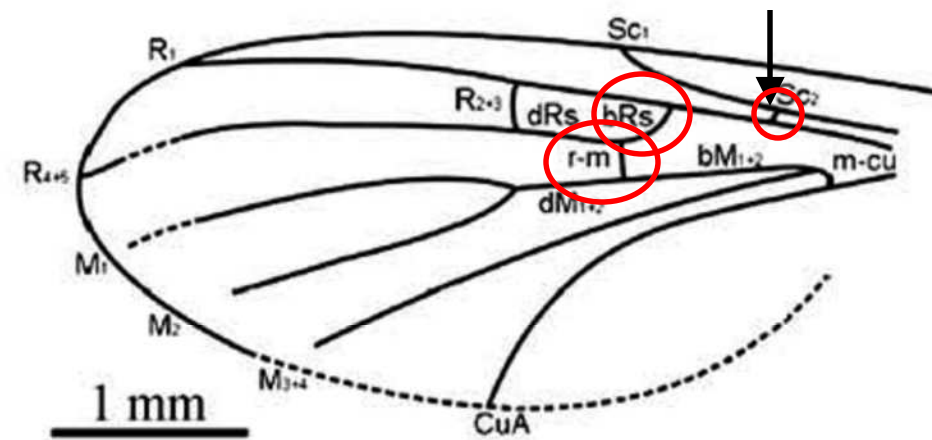
## Case Study 1:

# Dipteran genus transition

- Comparison using wing venation patterns between the genera.
- Known genera:
  - *Mesosciophilina*; Middle Jurassic; regarded as having characteristics similar to common ancestor; cell r large; forking of r-m shorter than bRs.
  - *Mesosciophilopsis*; Early Cretaceous; regarded as having derived characteristics since later in geologic time; cell r small; forking of r-m longer than bRs.
- New species:
  - Cell r small; forking of r-m shorter than bRs.
  - Venation characteristic of both known genera.

(Li and Ren 2009)

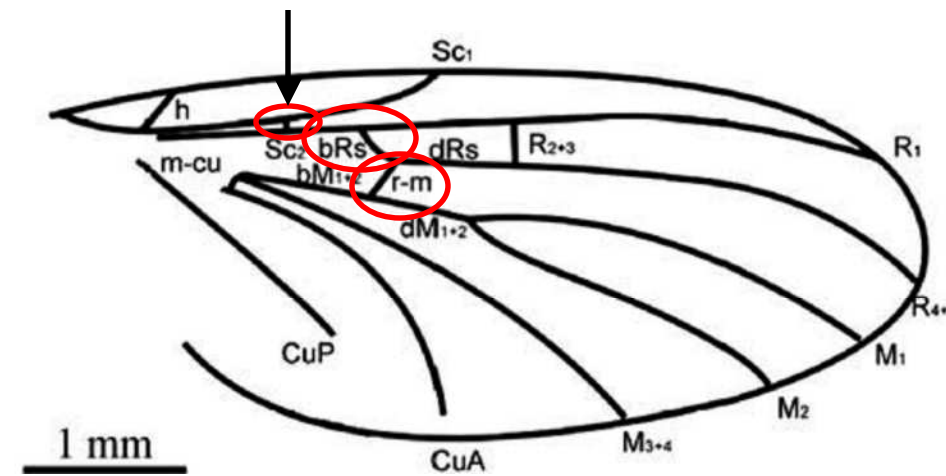
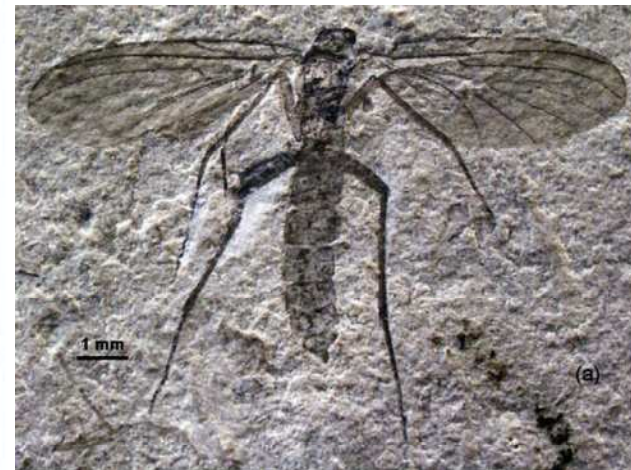
**Case Study 1:**  
***Jurasciophila curvula*** (species 1)



(Li and Ren 2009)

**Case Study 1:**

***Jurasciophila lepida* (species 2)**



(Li and Ren 2009)



## Case Study 2:

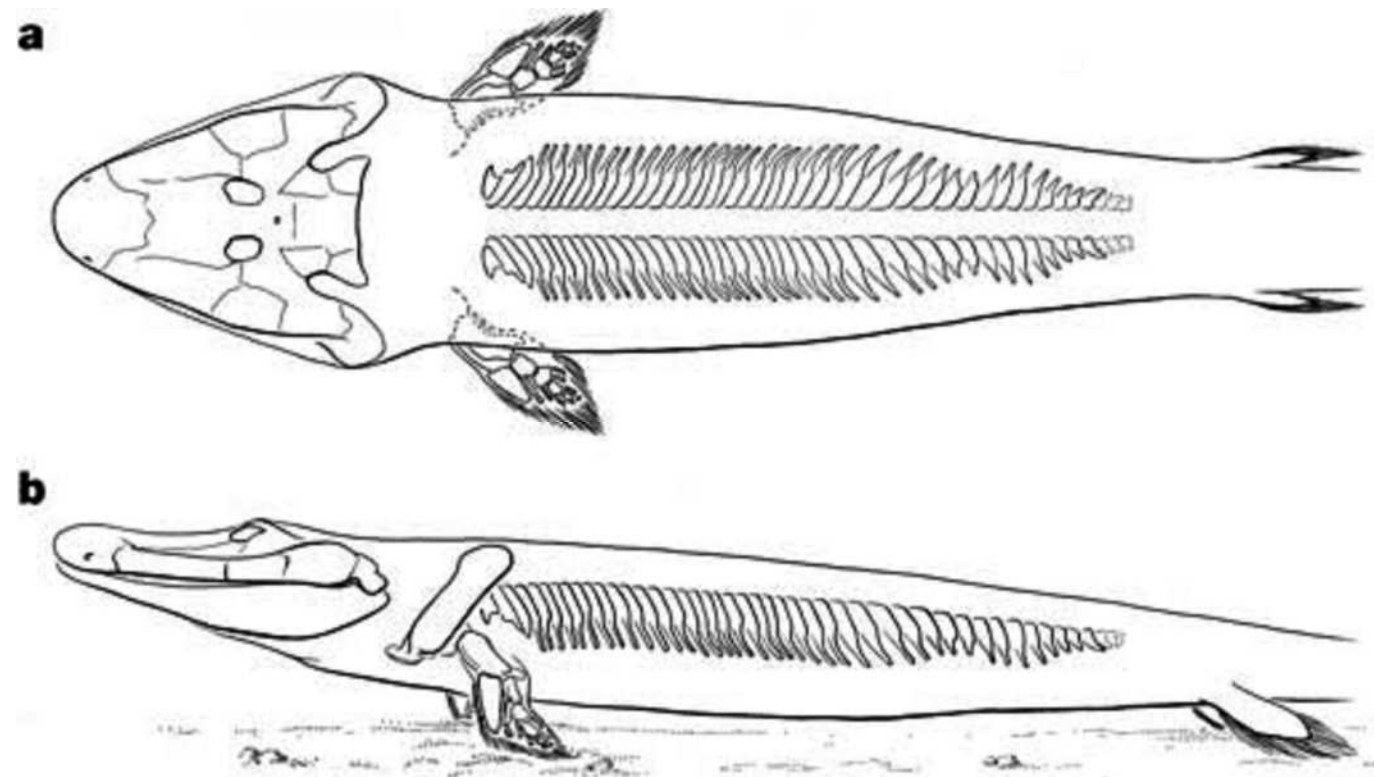
# Lobe-finned Fish-like Transition

- *Tiktaalik roseae* (sarcopterygian fish).
- Found in Nunavut, Canada from the Late Devonian (~360mya).
- New *Tiktaalik roseae* fossils share transitional characteristics between primitive fish and early tetrapods.

(Daeschler *et al.* 2006; Boisvert 2009)

**Case Study 2:**

***Tiktaalik roseae* (skeleton reconstruction)**



(Daeschler *et al.* 2006; Boisvert 2009)





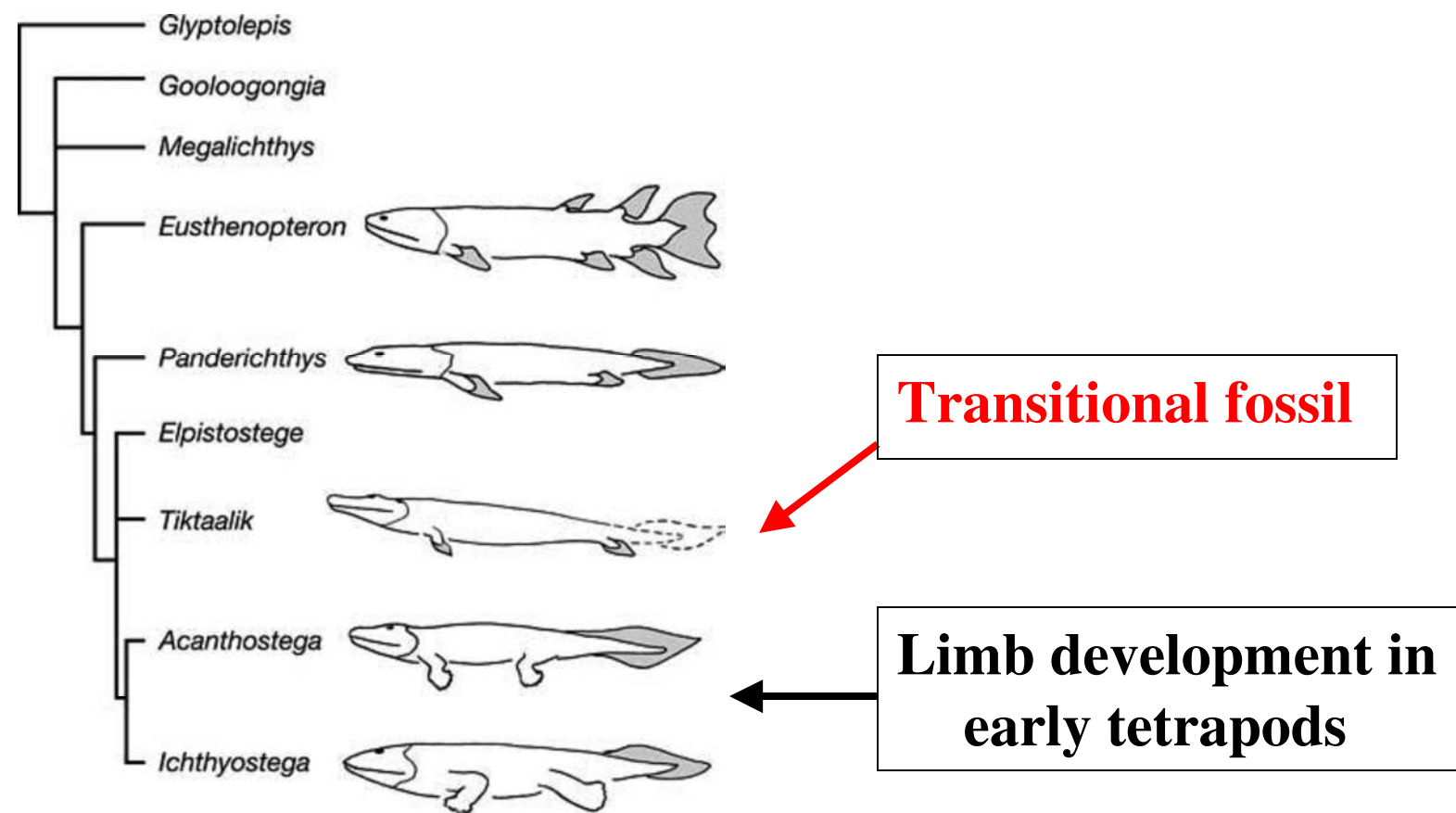
## **Case Study 2:**

### **Tiktaalik as an Intermediate Transition**

- Serve as intermediate between fish (with fins) and tetrapods (with limbs).
- Characteristics:
  - Primitive fish-like body scales, fin rays, lower jaw and palate.
  - Tetrapod-like shortened skull roof, modified ear region, mobile neck and functional wrist joint.
- Provides insight of order tetrapod characters arose.

(Daeschler *et al.* 2006; Boisvert 2009)

## Case Study 2: Phylogenetic relationships of fish-like tetrapod evolution



(Daeschler *et al.* 2006; Boisvert 2009)

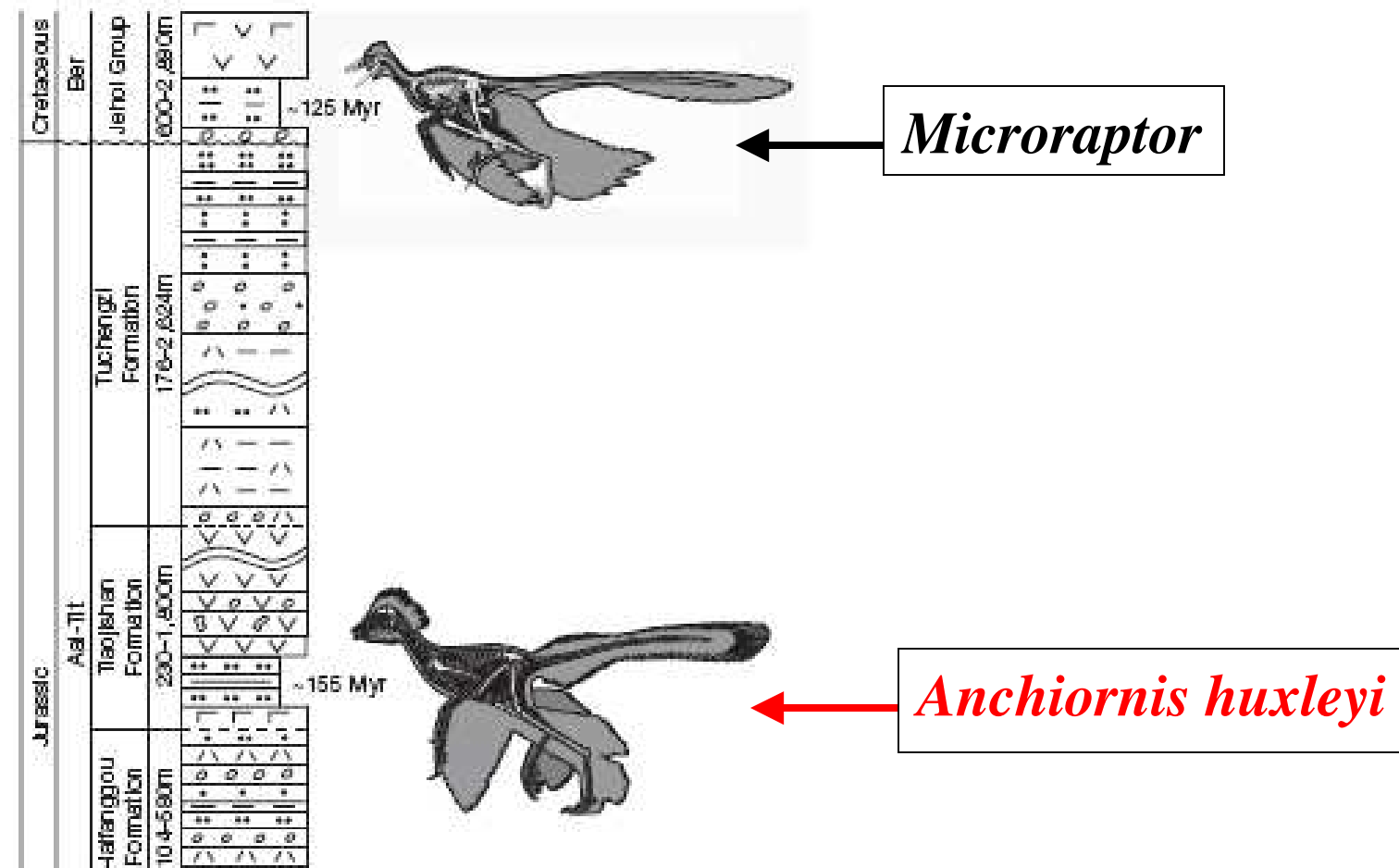


## Case Study 3: Non-avian Dinosaur-Bird

- *Anchiornis huxleyi* (feathered troodontid).
- Found in Tiaojishan Formation, China from the Late Jurassic (~161-151mya).
- *Anchiornis* retains basic dinosaur features; however, forelimbs longer than other troodontids and similar to avian dinosaur-birds.

(Xu *et al.* 2009; Hu *et al.* 2009)

## Case Study 3: Non-Avian Dinosaurs



(Xu *et al.* 2009; Hu *et al.* 2009)



## Case Study 3:

### Unique Characteristics of *Anchiornis*

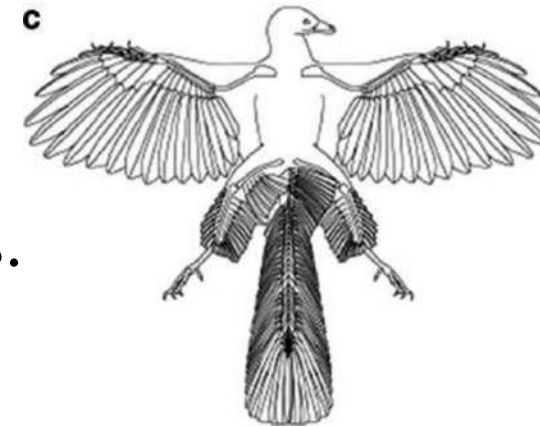
- Extensive feathering in organized planar surface.
- 2 types of plumulaceous feathers.
- Phylogenetic analysis places species as basal troodontid with direct avian ancestors (*Avialae*).

(Xu *et al.* 2009; Hu *et al.* 2009)

## Case Study 3:

### Unique Characteristics continued...

- Extreme elongation of lower legs.
- Proportionally large hindlimb feathers in addition to forelimb.



(Xu *et al.* 2009; Hu *et al.* 2009; Hutinson and Allen 2009)



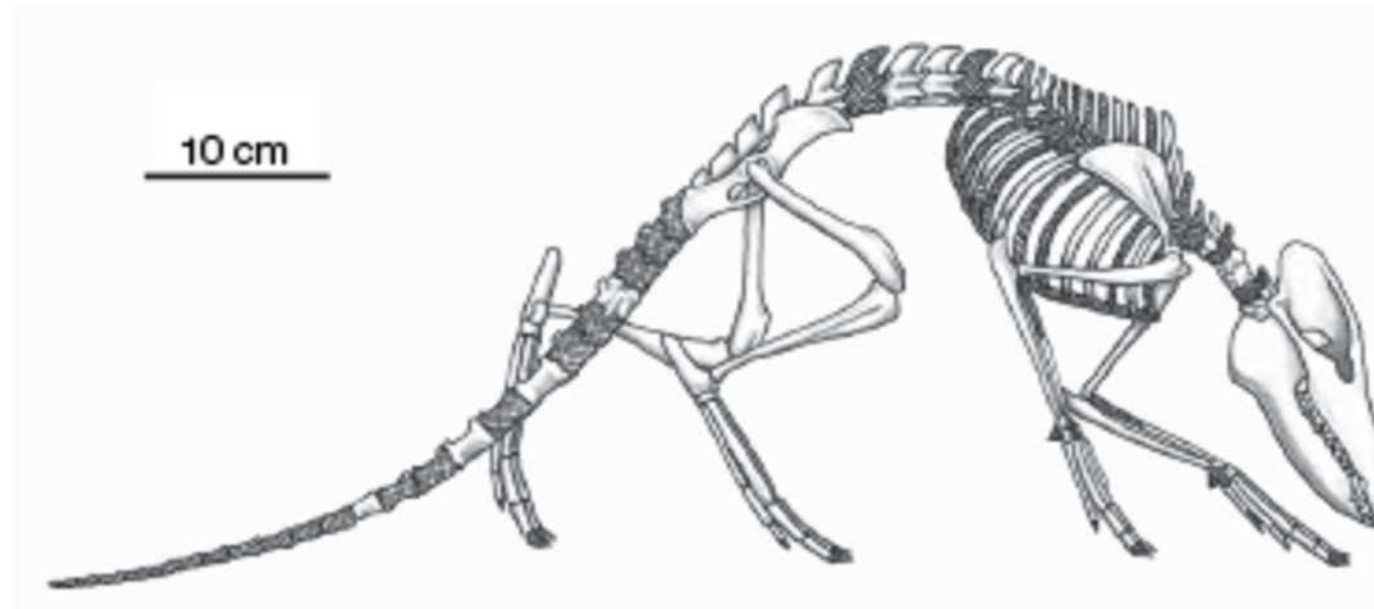
## Case Study 4:

# An Aquatic Whale-like Mammal

- *Indohyus* (even-toed ungulate, Order Artiodactyl).
- Found in Kashmir, India from the Middle Eocene (~45mya).
- *Indohyus* fossil shares similarity with whale ear structures, premolars and limb bone density; however, limbs are not modified into paddles and still retains mammal-like posture.

(Prothero 2005; Thewissen *et al.* 2007)

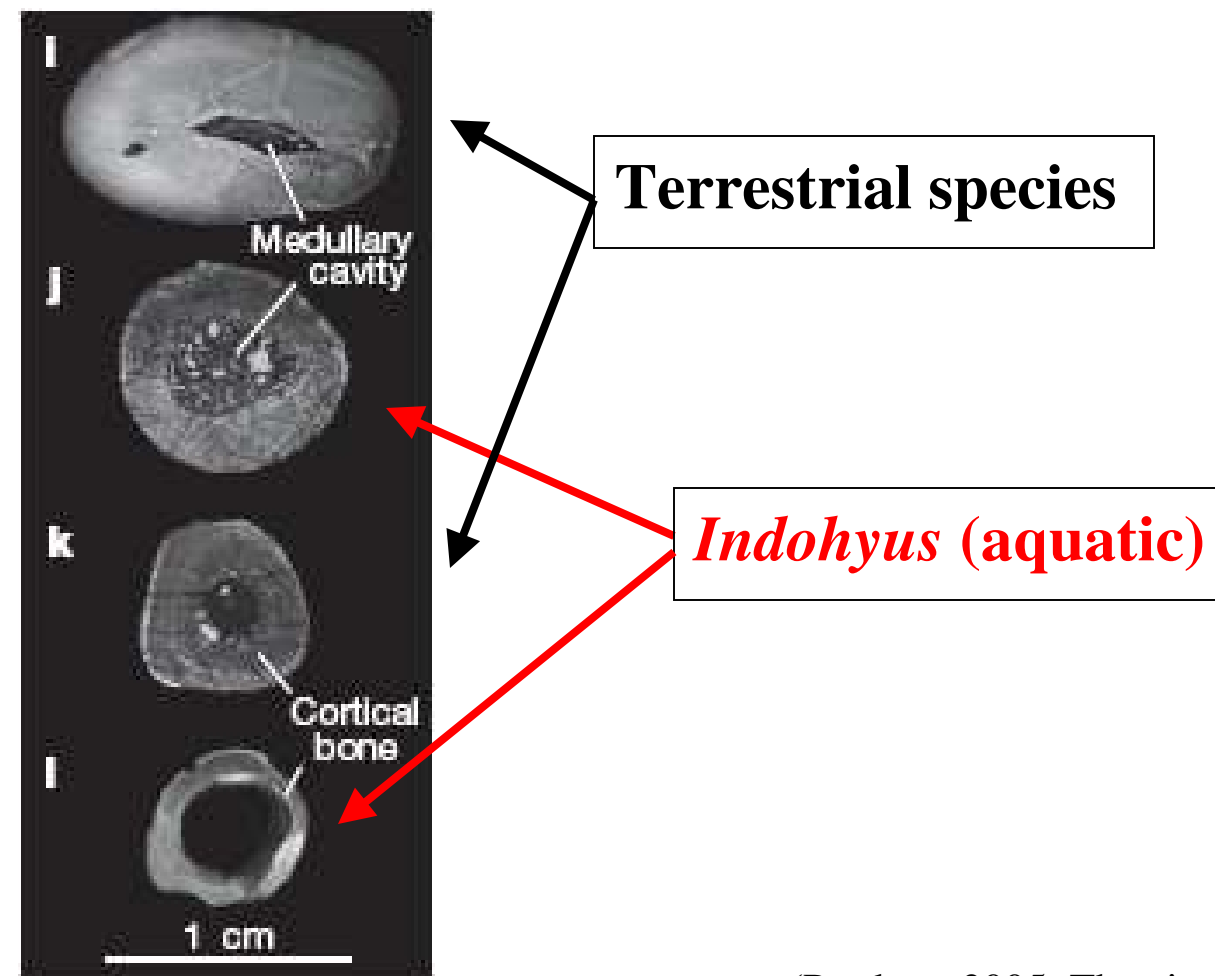
**Case Study 4:**  
**Indohyus** (skeleton reconstruction)



(Prothero 2005; Thewissen *et al.* 2007)



## Case Study 4: *Indohyus* Bone Osteosclerosis



(Prothero 2005; Thewissen *et al.* 2007)



## Case Study 5:

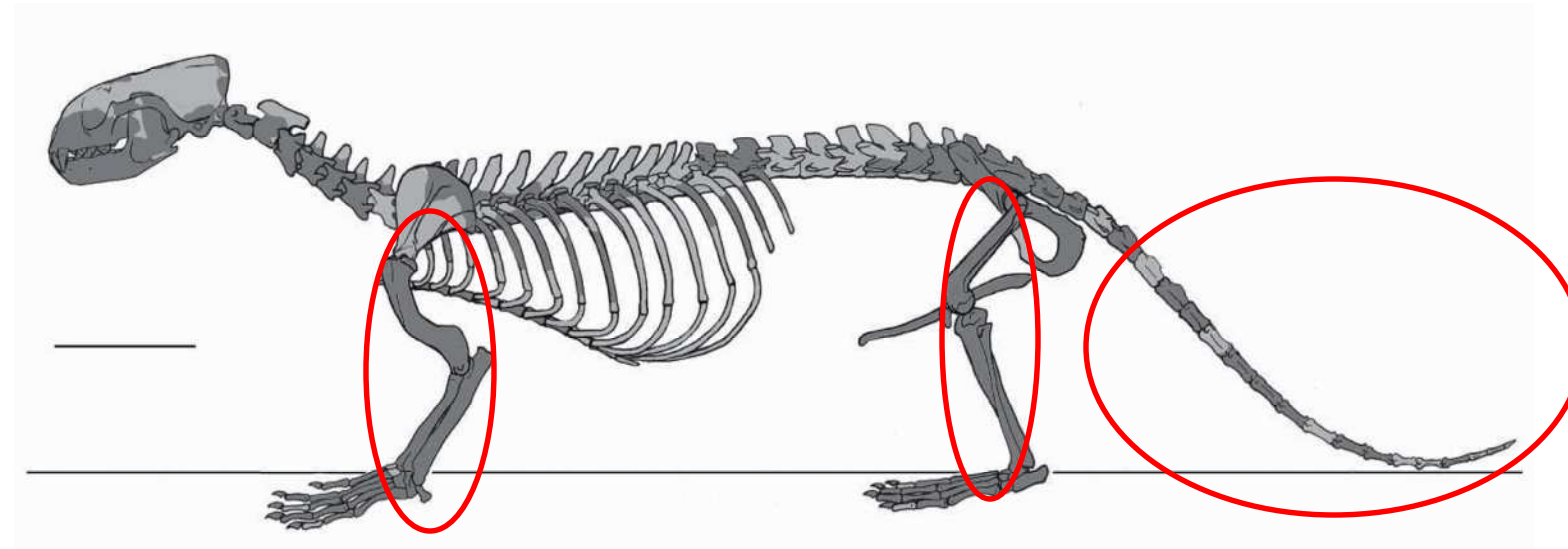
# Primitive Land-Sea Mammal

- *Puijila darwini* (small carnivore).
- Found in Nunavut, Canada from the Early Miocene (~23mya).
- *Puijila* fossil is morphological intermediate of land to sea transitional mammals.  
(such as the pennipeds or fin-footed mammals)

(Rybczynski *et al.* 2008)

# Case Study 5: Semi-Aquatic Transitional Adaptation

(Skeletal Reconstruction)



(Rybczynski *et al.* 2008)



## **Case Study 5:** **Continuous Land to Sea Transitions**

- Transition associated with innovations of locomotion, feeding and reproduction.
- Major transformational gap between terrestrial ancestor and appearance of flippered pinnipeds.
- Many modern flippered pinniped species:
  - E.g., manatees, sea otters, sea lions.


(Rybczynski *et al.* 2008)



## Conclusions

- Transitional fossils provide new insights for ancestry lineages and fill in relatively unknown gaps in the geological timescale.
- Evolutionary relationships between extant and extinct species illuminate developmental pathways.

(Paterson 2002)



## **General Implication of** **Transitional Fossils**

- The linear development of characters in a lineage can be inferred by transitional fossils.
- Provide ecological significance of characters retained from ancestors.
- Relate form and function.

(Paterson 2002)



## Discussion Questions

- How useful are transitional fossils for bridging animal groups/lineages?
- What kind of morphological traits were lost or gained for the discussed transitional fossils?
- Do changes in biodiversity play a role in the occurrence of transitional fossils?



## Discussion Questions

- How troublesome can incorrect interpretations of transitional fossils be to these bridges?
- Do biases from varying groups contribute or falsify the bridges?
- How are transitional fossils viewed by present religious and scientific communities? How do they compare/contrast?