The importance of transitional fossils in reference to relationships between species form and function

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Introduction

Gradual morphological changes over time can result in the development of a new species or specifically a transitional form between an ancestral and derived individual (Gingerich 1985). Detailed fossil records allow ancestral lineages to be traced over geological periods; however, the rate of morphological evolution and species turnover is rarely documented (Gingerich 1985). In actuality, detailed fossil records are difficult to manage as gaps between geological periods can occur due to many factors such as environmental conditions at the period of decomposition (Gingerich 1985). However, some transitional fossils have been documented (Daeschler *et al.* 2006; Thewissen *et al.* 2007; Li *et al.* 2008; Boisvert 2009; Hu *et al*. 2009; Rybczynski *et al.* 2009).

The study of transitional fossils is of particular interest since the discovery of these fossils is so rare and unique (Gingerich 1985). The aim of this paper is to review the importance of transitional fossils when relating animal forms and characters to possible locomotive, feeding or reproductive functions. In particular, the following three case studies will be analyzed: the dinosaur to bird transition; the land to sea mammal transition; and the fish to tetrapod transition. This paper will overview the general aspects of each case study while also presenting possible functions that may have led to the presence of characters in the transitional fossil itself.

The Dinosaur to Bird Transition

The transition between avian members and dinosaur descendants can be investigated using the smallest non-avian fossil, *Anchiornis huxleyi* that was discovered in sedimentary deposits in China (Hu *et al.* 2009; Xu *et al.* 2009). This species shares characteristics belonging to both avian descendants and theropod dinosaurs (Xu *et al.* 2009). Dated from the Late Jurassic, *Anchiornis* portrays transitional wrist features suggestive of wing folding mechanisms as well as more specialized wing mobility (Xu *et al.* 2009). These adaptations to the forelimb wrist joints are features closely resembling avian members (both extant and extinct). In addition to wrist evolution, *Anchiornis* also bears an extensive and organized feathering on the fore- and hindlimbs (Hu *et al.* 2009). Commonly, theropod dinosaurs have variable degrees of feathering on the fore- and hindlimbs; however, the relatively elongated forelimbs of *Anchiornis* compared to its fellow theropod relatives suggest evolutionary adaptation (Hu *et al.* 2009; Xu *et al.*2009). Phylogenetic analyses using theropod relatives and avian members have placed *Anchiornis* as a basal theropod member with the closest relation to avian features (Hu *et al.* 2009). Therefore, the transitional fossil, *Anchiornis* serves as a component joining the relationship between basic dinosaur locomotion to the modern bird flight adaptation (Hutchinson and Allen 2009).

The Land to Sea Mammal Transition

Adaptation behaviour related to environmental cues, such as changes in resource allotment can cause species to respond with transitional shifts from one environment to another. The small mammalian carnivore, *Puijila darwini* is a transitional fossil that shares both terrestrial and aquatic features characteristic to both types of environment (Rybczynski *et al.* 2009). *Puijila* is a semi-aquatic fossil found in Nunavut, Canada and dated to the Early Miocene epoch (Rybczynski *et al.* 2009). This mammalian species is suggested to be an early transitional form of pinniped (or sea lion) that developed from terrestrial mammalian ancestors (Rybczynski *et al.* 2009). *Puijila* has retained many of its terrestrial morphological features such as the large sized fore- and hindlimbs and a long tail; however, the flattened nature of the phalanges may indicate a transition to fin-like structures or webbed digits (Rybczynski *et al.* 2009). In conjunction with the *Puijila* fossil, a similar but earlier mammalian fossil, *Indohyus* demonstrates the transitional features resembling both terrestrial and aquatic animals (Thewissen *et al.* 2007). Belonging to the mammalian order Artiodactyla, the *Indohyus* fossil dates to the Middle Eocene (about 20my before the *Puijila* fossil) from a bone bed in India (Thewissen *et al.* 2007). Similarly, the *Indohyus* fossil also possesses large fore- and hindlimbs, a long caudal tail and flattened, long phalanges (Thewissen *et al.* 2007). The comparison between these two fossils at varying geologic times may suggest that the *Indohyus* fossil is more closely related to terrestrial mammals than *Puijila* due to its geologic age; however, a closer phylogenetic examination of both genera in relation to characters possessed should be conducted (Thewissen *et al.* 2007; Rybczynski *et al.* 2009). Despite the uncertainty of which fossil bears closer relation to sea dwelling mammals, both the *Puijila* and *Indohyus* fossils clearly resemble their terrestrial and aquatic mammalian relatives and are beneficial as transitional fossils.

The Fish to Tetrapod Transition

As an intermediate transitional fossil between lobe-finned fish and 4-legged tetrapods, *Taktaalik roseae* shares features characteristic to both types of animals (Daeschler *et al.* 2006). The *Taktaalik* fossil was discovered in Nunavut, Canada from the Late Devonian and seemingly possessed very few tetrapod characteristics (Daeschler *et al.* 2006). The outer surface of the *Taktaalik* fossil is covered in fish-like body scales as well as possessing fin rays and a lower jaw and palate that would have resembled the primitive fish relative rather than tetrapods (Daeschler *et al.* 2006). A closer examination of the fossil illustrates skeletal subtleties that would be characteristic of an early tetrapod; such as, the shortened skull roof, modified ear region for more terrestrial environments, mobile neck and a functional wrist joint (Daeschler *et al.* 2006). It is clear that the *Taktaalik* fossil resembled both fish and tetrapods while serving as an intermediate component between them both. The early development of the modified ear region and mobility of the head suggests the sequential order that defines tetrapod species development (Daeschler *et al.* 2006; Clack 2009). In addition to possible developmental sequences present in early tetrapod evolution, the mobility of the head may be indicative of body support required to live in new and possibly sub-aerial environments, characteristic to tetrapod evolution (Daeschler *et al.* 2006). All things considered, the *Tiktaalik* fossil provides insight into the developmental and habitual characteristics of early tetrapod evolution.

Conclusions

Transitional fossils can provide new insights for ancestry lineages while fulfilling relatively unknown gaps in the geological timescale with potential links. The importance of evolutionary relationships between extant and extinct species can serve as precursors for common patterns in development. The adaptation of the three case studies discussed demonstrated the beneficial role of transitional fossils when combining relationships between species: non-avian dinosaurs with feathers and long forelimbs join dinosaur with bird; the elongated and flattened phalanges of semi-aquatic mammals unite land and sea dwelling species; and the development of increasingly mobile necks for shallower waters may connect fish with tetrapods. To conclude, gradual morphological evolution of form can be linked with reasonable physical or behavioural function considering the transitions are known.

References
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