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FEATHERED DINOSAURS RECONSIDERED: NEW INSIGHTS FROM BARAMINOLOGY AND ETHNOTAXONOMY

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ABSTRACT

Birds could not have evolved from land animal ancestors because Genesis clearly states that birds and land animals were created on separate days. As a result, young-earth creationists have consistently opposed the theory that birds evolved from dinosaurs. Nevertheless, numerous fossils of dinosaurs with feathers, including some very bird-like dinosaurs, have been found in the late 20th and early 21st centuries. We determined to understand what these fossils mean in a creationist context through a survey of their fossil record and statistical baraminological analyses. While the survey demonstrates that feathered dinosaur fossils do, in fact, exist, the baraminological analyses suggest that there are probably at least eight different created kinds of non-avian dinosaurs. The existence of multiple created kinds of non-avian dinosaurs, non-avian avialans, and avians without an enormous morphological gulf between these groups, although historically unexpected in creationism, is argued through this study to be an accurate picture for their designed organization. Because of these results, creationists need to rethink the way they understand the organization of life, especially as it relates to tetrapods, in order to better represent the full spectrum of God’s created variety.

KEY WORDS

Dinosauria, feather, *Archaeopteryx*, ethnotaxonomy, baraminology, Theropoda, discontinuity, baraminic distance correlation, multidimensional scaling

INTRODUCTION

1. *Archaeopteryx* and Early Thoughts on Bird Evolution

Paleontologists have long noted the similarities between dinosaurs and modern birds. *Archaeopteryx lithographica* was discovered in 1861, just two years after the publication of *Origin of the Species*. Since then, it has become the centerpiece in the theory that modern birds are descended from dinosaurs. Thomas Huxley was the first to propose that *Archaeopteryx* was an intermediate form between dinosaurs and birds, and even linked the two groups before a more complete specimen of *Archaeopteryx* was described (Huxley 1868; Huxley 1870).

Looking at the fossils, such as the exemplary Berlin Specimen (Fig. 1), one can easily see how this conclusion was drawn. The feathers obviously remind one of birds. However, as one observes the skeleton in detail, one begins to notice numerous features similar to theropod dinosaurs, which are not found in birds. *Archaeopteryx* has hands with three distinct fingers terminating in claws, unlike the fused wingtips in modern birds. While the tails of modern birds are very short and made up of a small number of fused vertebrae called a pygostyle, *Archaeopteryx* possesses a long, bony tail. Other features include a jaw with teeth, rather than a toothless beak; gastralia (or “belly ribs”); a hyperextendable claw on the second toe, similar to dromaeosaurids; and a greatly reduced fifth toe. In fact, bones from *Archaeopteryx* look strikingly similar to those from *Compsognathus*, a small theropod found in the same localities.

In 1927, the Danish paleontologist Gerhard Heilmann wrote the influential book *The Origin of Birds*. Like many paleontologists at the time, Heilmann noted the similarities between *Archaeopteryx*



Figure 1: “Berlin Specimen” of *Archaeopteryx lithographica* located in Natural History Museum, Vienna. Photo by Wolfgang Sauber licensed under CC BY-SA 3.0.

and theropods, such as the contemporary *Compsognathus*. Despite recognizing the strong parallels between the two groups, Heilmann refused to conclude that birds evolved from dinosaurs due to one missing piece of evidence he considered critical: dinosaurs did not possess clavicles, much less a furcula (the set of fused clavicles in birds commonly referred to as the “wishbone”). Heilmann concluded that birds must have an ancestor within Pseudosuchia, which contained specimens known to have clavicles. In 1924, the theropod *Oviraptor* was discovered in Mongolia by Henry Fairfield Osborn. This specimen possesses a furcula, but it was misidentified in the original paper (Barsbold 1983; Osborn 1924). Just over a decade later, the Lower Jurassic theropod *Segisaurus* was found with an unmistakable clavicle, which under later review was found to be a furcula (Carrano et al. 2005).

Heilmann’s view on the origins of birds was generally accepted through the 1950s. In 1964, paleontologist John Ostrom discovered *Deinonychus*, a new species of dromaeosaurid – a small theropod with a large, sickle-shaped “killing claw” on the second toe. Through the early 1900s, dinosaurs were predominantly portrayed as sluggish, reptilian ectotherms. *Deinonychus*, however, was clearly an active and agile predator (Ostrom 1969). In addition to this, Ostrom (1974) noticed many similarities between the forelimbs of *Deinonychus* and *Archaeopteryx* (Fig. 2). In fact, *Deinonychus* shows numerous striking skeletal similarities to *Archaeopteryx*. For instance, *Deinonychus* had features that most theropods known at the time did not, such as a birdlike hip structure with a retroverted pubic bone (vertical, according to Senter et al. (2012)), a semilunate carpal bone (a wrist joint that allows birds and other maniraptorans to fold their hand against the forearm) much like that of *Archaeopteryx*, and likely feathers (several other fossil dinosaurs in the same family have been found with feathers) (Kane et al. 2016). Earlier restorations of *Archaeopteryx* depicted it with a fully reversed hallux like a modern perching bird (Morell 1993), but newer specimens with less distortion have confirmed toe positions in *Archaeopteryx* to be the same as in deinonychosaurs (Fowler et al. 2011; Mayr et al. 2007; Mayr and Peters 2007), although there are dissenters to this opinion (Feduccia 2007; Feduccia et al. 2007).

2. What Is a Feather?

Many creationists, and some evolutionists, have been hesitant to call the fuzzy structures present in many dinosaur fossils “feathers”. Some have suspected that the structures are actually degraded dermal collagen tissue (e.g., Feduccia et al. 2005; Lingham-Soliar et al. 2007), whereas others recognize them as “dino fuzz”, an indeterminate form of integument unrelated to feathers. Microscopic examination of the filaments in *Sinosauropteryx* suggest that they were hollow, similar to feathers (and very different from mammalian hair). Further analysis has revealed preserved melanosomes in the structures, suggesting they are not collagen, as collagen does not contain pigment (Longrich 2002). Additionally, chemical analysis of similar structures in the alvarezsaurid theropod *Shuvuuia* has revealed the presence of β -keratins, but no α -keratins. β -keratins are only produced by the epidermal cells of non-avian reptiles and birds, and feathers are the only structures known that consist entirely of β -keratin (Schweitzer et al. 1999).

There have been claims that feather impressions have been carved

onto some fossils, even *Archaeopteryx* (Halstead 1987; Hoyle and Wickramasinghe 1986; Hoyle et al. 1985a; Hoyle et al. 1985b; Hoyle et al. 1985c; Spetner et al. 1988; Trop 1983). Most of the Chinese specimens have feathers preserved as carbonaceous films, which means that they could not have been simply carved. The London *Archaeopteryx* specimen (the neotype) has been studied under scanning electron microscopy and UV light photography, and the authors demonstrated that the feather imprints were genuine (Charig et al. 1986). Additionally, the Thermopolis *Archaeopteryx* specimen has been studied under synchrotron rapid scanning X-ray fluorescence, which revealed that portions of the feathers were not impressions but actual body fossil remains with distinct chemical signatures (Bergmann et al. 2010).

Xu and Guo (2009) define modern feathers as “complex integumentary appendages formed by hierarchical branches of rachis, barbs, and barbules which are composed of Φ -keratins and grow from a follicle”. However, we cannot automatically assume that the spectrum of feather types present today (and there are many) encompasses all feather types that have ever existed. To distinguish some feather-like fossils in the fossil record from modern feathers, some evolutionists have used the term “protofeather”, but this implies that these structures are ancestral to modern feathers. Xu and Guo (2009) described eight different feather morphotypes that they noted in fossils of non-avian dinosaurs, including “basal” avialans (Fig. 3). Some of these morphologies are bizarre when compared to modern feather types (especially morphotypes 2, 5, and 8, which are B, E, and H in Figure 5), which has led some researchers to suspect that they might be influenced by taphonomic processes (e.g., Benton et al. 2008). For instance, contact with water causes a loss of morphological information resulting in feathers taking on a filamentous morphology (Kundrát 2004). A major taphonomic influence on feather preservation in fossils is compaction. Foth (2012) conducted an actualistic experiment where he flattened a cadaver of a *Carduelis spinus* (European siskin) in a printing press to simulate the compaction of many non-avian theropods in the Jehol Beds of China. The flattened feathers appear filamentous like in non-avian dinosaur fossils, which means that the original feather morphology is essentially unrecognizable. Additionally, some feather barbs appear to have stuck together because of the discharge of body fluids during compaction, which results in artificial “fused” structures. Taphonomic considerations combined with observations of modern avian plumage lead Foth (2012) to conclude that morphotypes 2, 5, and 8 (Fig. 3B, 3E, and 3H) are probably not real feather types, but taphonomically-altered more normal feather types.

A recent discovery has given paleontologists new insight into ancient feather types: a portion of a feathered tail trapped in amber (Xing et al. 2016). Although it was difficult to clearly visualize the morphologies of the caudal vertebrae, Xing et al. (2016) concluded that the tail belonged to a non-avian coelurosaur because of the vertebral profiles and estimated length. The amber exquisitely preserved some feathers which showed a previously unknown morphology of barbules branching not only within individual barbs, but also from the rachis, which appears to have been flexible. These feathers could not have been used for flight, but may have been used in display or insulation.

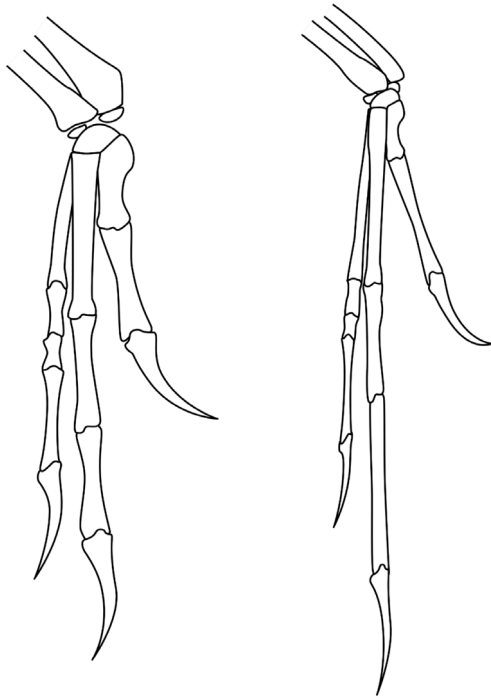


Figure 2. Hands of Deinonychus (left) and Archaeopteryx (Right). Illustration by John Conway. CC BY-SA 3.0.

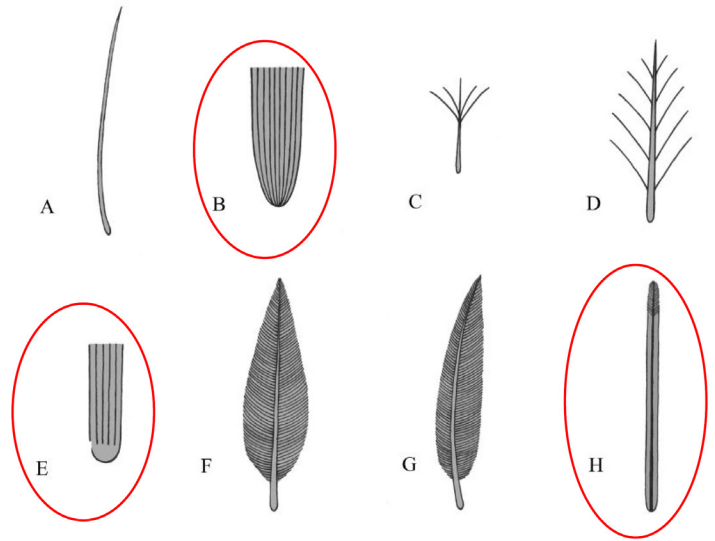


Figure 3. Eight feather morphotypes of Xu and Guo (2009). The three feather morphotypes questioned by Foth (2012) are circled. Image modified from Figure 4 of Xu and Guo (2009) and used with permission from *Vertebrata Palasiatica*, sponsored by the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China.

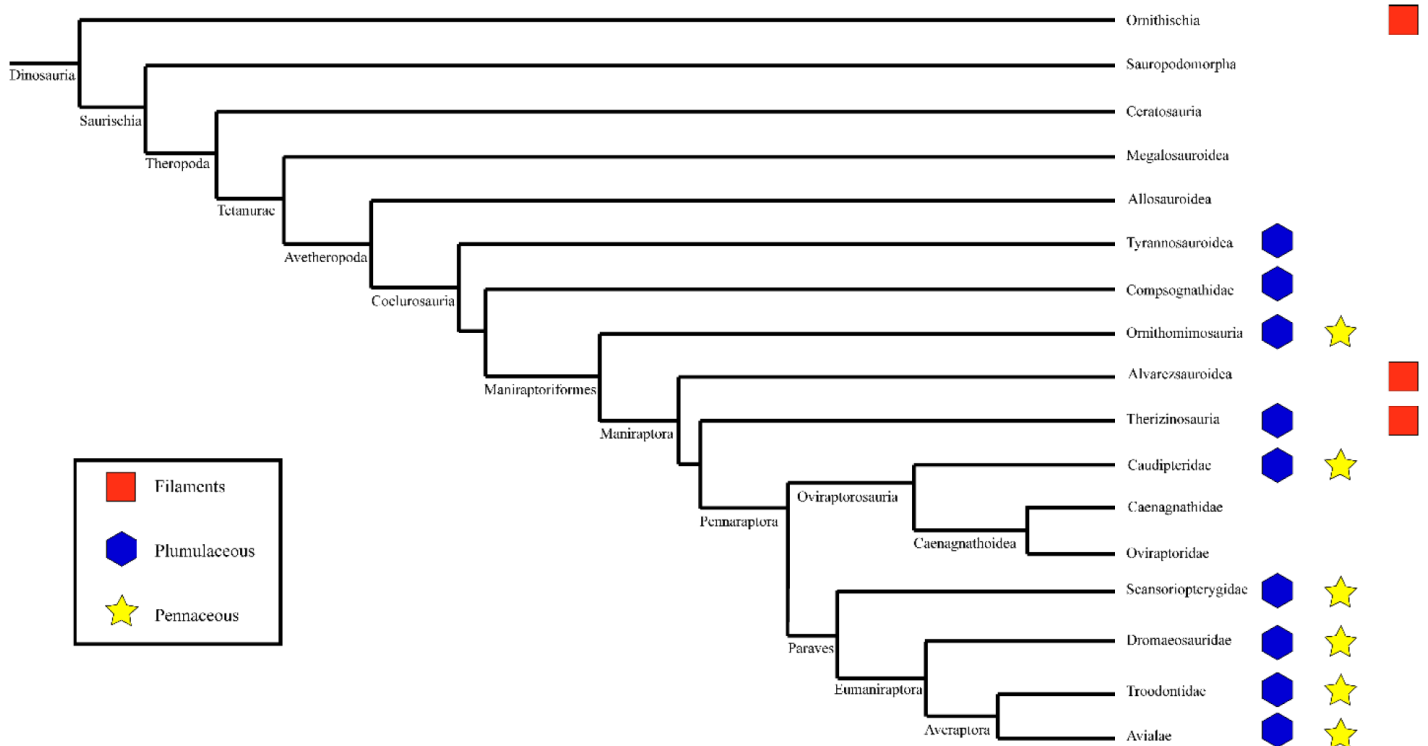


Figure 4. Simplified cladogram of feathered dinosaurs. Types of feathers have been indicated by symbols as described in the legend. Cladogram and feather data from Hendrickx et al. (2015); Lefèvre et al. (2014); and Prado et al. (2015).



Figure 5. Holotype of *Sinosauropteryx prima* showing integument. <https://www.flickr.com/photos/50159489@N00/1492438954/> Dinosaurs! by <https://www.flickr.com/people/50159489@N00> Sam / Olai Ose / Skjaervoy. <https://creativecommons.org/licenses/by-sa/2.0/deed.en> CC BY-SA 2.0.

3. Survey of Feathered Dinosaurs

Though hypothesized, there was no direct evidence of definite dinosaurs possessing feathers until the late 20th century. This changed in 1996 with the discovery of *Sinosauropteryx*. Since then, there have been dozens of taxa reported to have inferred and direct evidence of feathers in each of the major coelurosaurian clades (Fig. 4). What follows is a non-exhaustive survey of dinosaurs known to have feathers.

Compsognathids are a group of theropods known for their small size and relatively large thumbs. In 1996, the tiny theropod *Sinosauropteryx*, a compsognathid, was found in the Liaoning Province of China (Chen et al. 1998). The most striking feature of the holotype is the ridge of short, filamentous integument running

down the head, neck, back, and top and underside of the tail (Fig. 5). Other specimens have ventral patches of this integument, suggesting the entire body would have been covered in life. A larger compsognathid, *Sinocalliopteryx*, was described in 2007 and known to be covered in filamentous feathers (Ji et al. 2007). While feathers were found in expected areas such as the flank, hips, and tail (Fig. 6), they were also found on the upper foot.

Tyrannosauroids are small-to-large theropods best known for the famous tyrannosaurids (e.g., *Tyrannosaurus*, *Albertosaurus*, etc.), which possessed large, deep skulls and reduced arms. However, Tyrannosauroidea is a broader group, and includes smaller animals that share similarities with their larger relatives (Holtz 2004). The first evidence of feathers in this group was documented in

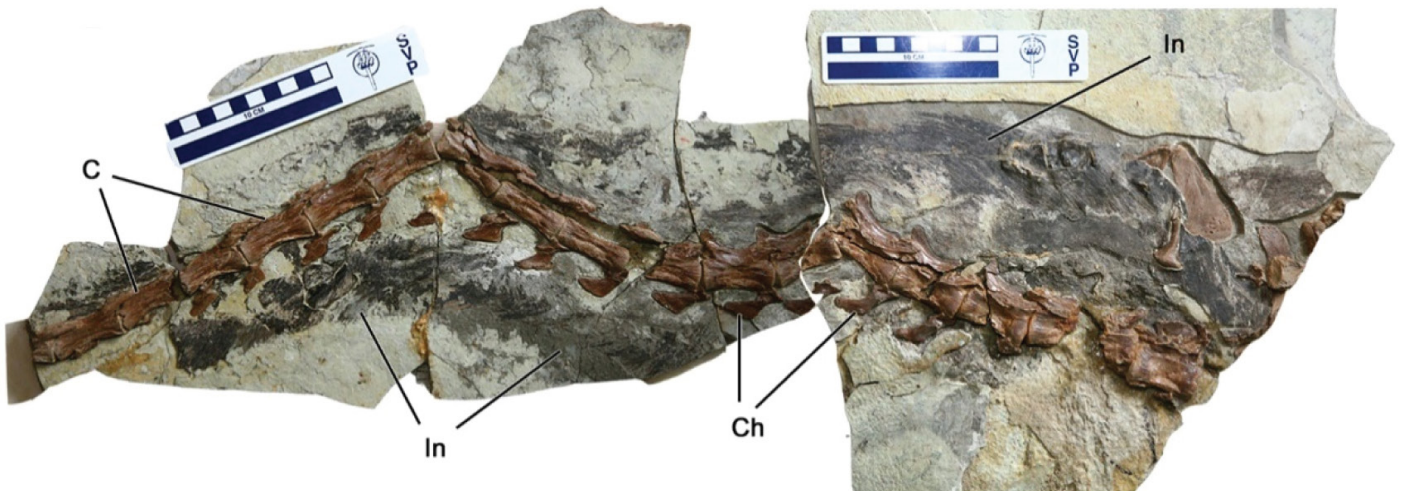


Figure 6. Filamentous integument along the tail of *Sinocalliopteryx*. Abbreviations: C, centrum; Ch, chevron; In, integument. Cropped from Xing et al. (2012), obtained via Wikimedia Commons. CC BY 2.5.

2004 in the small tyrannosauroid *Dilong* (Xu et al. 2004). Skin impressions from the jaw and tail reveal the animal was covered in feathers lacking a central shaft, much like downy feathers exhibited in modern birds. Such feathers would be useless for flight, but it is possible they were helpful in insulation or display. In 2012, the significantly larger *Yutyrannus* was found in Lower Cretaceous deposits in Liaoning, China (Xu et al. 2012). The body of *Yutyrannus* was covered in large, filamentous feathers up to 200 mm long. Feathers are known from the neck, arms, feet, pelvis, and tail, and may have played a role in thermal regulation (Fig. 7). It is worth noting that the larger tyrannosaurids, such as *Tyrannosaurus*, are known to have been scaly in some places where feathers are present in *Yutyrannus*, perhaps indicating that feathers were lost as members of the group reached massive body sizes (Bell et al. 2017). At nearly 9 meters long, *Yutyrannus* is the largest known dinosaur with direct evidence of feathers.

Ornithomimosaurs are slender, bipedal theropods known for their long limbs, necks, and toothless beaks, and their superficial similarity to ostriches. When *Ornithomimus* was named in 1890, it was thought to have been entirely covered in scales until specimens with feathers were first discovered in 1995 (but not recognized as feathers until over a decade later). The feathered specimens include

juveniles and adults, which indicates that the animal possessed feathers throughout its life. However, only the adults seem to have possessed pennaceous feathers on the arms, which may suggest that they were display structures (Zelenitsky et al. 2012). Others argue against the arm feathers being pennaceous, citing the similarities of the preserved *Ornithomimus* feathers to those of cassowaries (Foth et al. 2014). It is worth noting that the juvenile specimen bore feather impressions preserved in sandstone, previously thought to be impossible. This suggests feathers may be found in other fossils with more careful excavation (Zelenitsky et al. 2012). A specimen discovered in 2015 was found to have feathers of a similar structure and distribution as an ostrich (van der Reest et al. 2016). The massive *Deinocheirus*, long known only as a pair of gigantic front limbs, underwent a revision in 2014 when additional specimens were described, from which a near-complete skeleton could be reconstructed. In addition to revealing some very peculiar and unforeseen anatomical traits, the last two vertebrae are fused to form a pygostyle, indicating *Deinocheirus*, as well as other ornithomimosaurs, likely had a tail fan (Lee et al. 2014b).

Alvarezsaurids were small, specialized theropods with distinctive, highly reduced forelimbs and hands. Some species only had one claw, though two tiny claws are also present in *Shuvuuia*. *Shuvuuia* was found surrounded by structures resembling the central shaft of modern bird feathers. As noted before, these structures possess β -keratins, but not α -keratins, just as in modern feathers (Schweitzer et al., 1999).

Oviraptorosaurs are best known by their undeserved moniker “egg thieves.” Their beaked skulls were short and superficially similar to that of a parrot. Many species of oviraptorosaur have been found with pygostyles (Fig. 8), the first evidence of such being found in *Nomingia* in 2000 (Barsbold et al. 2000). Since then, species such as *Citipati* and *Conchoraptor* have been found with pygostyles (Persons IV et al. 2013). Direct evidence of feathers has been



Figure 7. Integumentary structures surrounding the tail of *Yutyrannus huali*. Image cropped and brightened from original photo by ★Kumiko★. CC BY-SA 2.0.

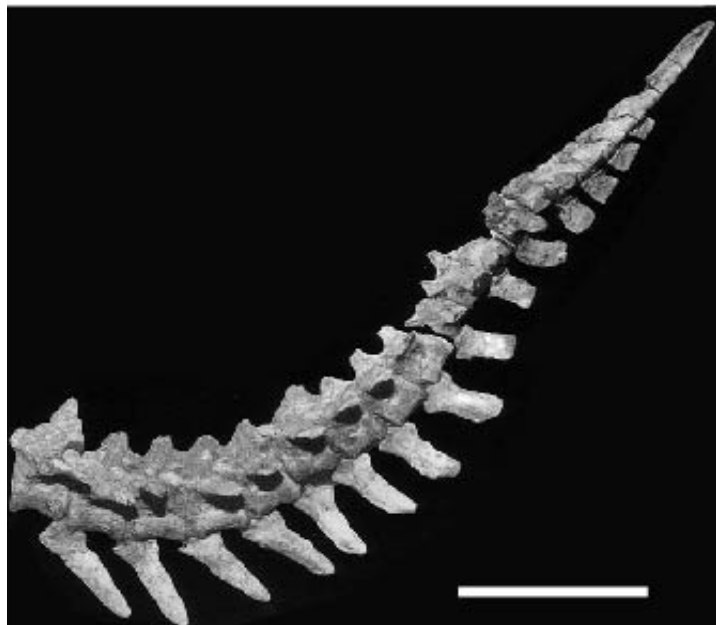


Figure 8. Left lateral view of the pygostyle of the oviraptorid *Nomingia gobiensis*. Scale bar 10 cm. Image modified from Barsbold et al. 2000, obtained via Wikimedia Commons. CC BY 2.0.

found in caudipterids, a family of oviraptorosaurs. *Caudipteryx* (Fig. 9) sported a tail fan of feathers, and was covered in down-like filaments (Ji et al. 1998; Zhou and Wang 2000).

While many creationists may be skeptical of inferring feathers when there are no feathers preserved, these predictors have proven to be an effective indicator of the existence of feathers. When the caudipterid *Similicaudipteryx* was found in 2008, paleontologists speculated that the animal likely possessed feathers based on the existence of a pygostyle (He et al. 2008). In 2010, two more specimens were found to be covered in downy feathers, with hands and tails sporting longer, symmetrical feathers (Xu et al. 2010).

Therizinosaurs are bizarre, medium-to-large sized herbivorous theropods with large bodies, long necks, short legs, and distinctive, large, scythe-like claws on their forearms. *Beipiaosaurus* is known to have had a coat of downy feather-like integument comparable to that of *Sinosauropteryx*, as well as a secondary coat of quill-like “elongated broad filamentous feathers” (Xu et al. 1999; Xu et al. 2009). Recent in-depth study of a *Beipiaosaurus* fossil (as well as fossils of other Jehol creatures including two dromaeosaurids (*Sinornithosaurus* and *Microraptor*) and the Mesozoic bird *Confuciusornis*) has revealed skin patches in the form of tiny epidermal flakes preserved with nanoscale detail in calcium phosphate (McNamara et al. 2018). These fossil corneocytes suggest that these animals shed their skin in flakes like mammals or birds. These fossil skin flakes are most similar to those of extant birds as seen in the fossil corneocytes’ central globular structures, which resemble dead cell nuclei as seen in depressions in the corneocyte surface in extant birds, but not in extant reptiles or mammals (McNamara et al. 2018).

Dromaeosaurids are a group of small-to-medium sized theropods famous for the large, sickle-shaped claw on the second toe. They are commonly referred to as “raptors” in popular culture. *Velociraptor* was long thought to have had feathers, based on the feathers known from its relatives, such as *Sinornithosaurus* (Figure 10). In 2007, a *Velociraptor* ulna was found with six small, evenly-spaced protrusions that perfectly resemble a structure seen in modern birds (Turner et al. 2007b). In birds, these knobs serve as anchor points for feathers. In 2000, the remarkable *Microraptor* was found in Lower Cretaceous strata in Liaoning, China. Fossils of *Microraptor* (Fig. 11A) show its body was covered in a thick coat of feathers, and it possessed four wings, with long flight feathers (Figure 11B) up to 200 mm long on each of its four limbs (Xu et al. 2003). Like birds, *Microraptor* had primary and secondary feathers, anchored to the hands/feet and arms/legs, respectively. Interesting to note is the striking similarity of *Microraptor* to William Beebe’s (1915) hypothetical bird ancestor “Tetrapteryx” drawn 85 years prior to the fossil’s discovery (Fig. 11C).

Troodontids are remarkably bird-like dinosaurs. They were lightly-built and had large brains, which implies they likely had very keen senses. In 2017, the troodontid *Jianianhualong* was described based on a complete specimen with preserved feathers (Xu et al. 2017). Feathers of indeterminate structure line the neck, back, and arms, and the tail sported a frond of pennaceous feathers, reminiscent of *Archaeopteryx*. However, unlike *Archaeopteryx*, the tail feathers of *Jianianhualong* are curved (Fig. 12).

Anchiornis is a dinosaur of questionable affinity, and its phylogenetic position is highly disputed, despite multiple essentially complete specimens (Fig. 13). Some studies group it with troodontids (Hu et al. 2009), while others consider it an avialan (Cau et al. 2017; Foth and Rauhut 2017; Godefroit et al. 2013), or even a sister taxon to Avialae (Lefèvre et al. 2017). Simple feathers covered the head, neck, body, legs, feet, and tail, with pennaceous feathers on the wings, legs, and tail (Li et al. 2010; Witmer 2009).

Scansoriopterygids are a group of unusual, likely arboreal theropods, possessing adaptations for climbing and gliding, including extremely elongated third fingers (Zhang et al. 2002). They are generally quite small, ranging between the size of a sparrow and a pigeon. *Scansoriopteryx* is known to have down-like feathers similar to modern feathers on the hand and lower arm, as well as the end of the tail, while scales are preserved at the base of the tail (Czerkas and Yuan 2002). *Epidexipteryx* was covered in short quill-like body feathers, and possessed four long, ribbon-like tail feathers. Unlike many theropods, *Epidexipteryx* seemed to lack arm feathers (Zhang et al. 2008). *Yi* is particularly interesting, even for a scansoriopterygid. Like many small theropods, *Yi* was mostly covered in feathers. However, *Yi* exhibits a critical difference in its wings – a membranous patch of skin stretching from its torso to the elongated third finger (Xu et al. 2015). *Yi* is the only known dinosaur possessing a styliiform, a wrist bone that helped support



Figure 9: *Caudipteryx zoui* cast exhibited in Houston Museum of Natural Science. Photograph dedicated to public domain by Daderot.

the membrane. The body was almost entirely covered in a thick coat of quill-like, tufted feathers (Fig. 14).

While most reports of feathers have come from theropod dinosaurs, they are not exclusive to them. While rare, filamentous integument has been documented in ornithischians. *Psittacosaurus*, a small ceratopsian, was found to have long quill-like structures near the base of the tail (Fig. 15). The bristles are clustered and filled with pulp (Mayr et al. 2002). *Tianyulong* (Fig. 16), a heterodontosaurid, had bristly integument along the neck, back and tail (Zheng et al. 2009). In 2014, the neornithischian *Kulindadromeus* was found with three different types of feather-like integument, including a type similar to *Sinosauropteryx*, in addition to scales (Godefroit et al. 2014). It is not certain if the structures in ornithischians are homologous to those in theropods, though the structures on *Psittacosaurus* and *Tianyulong* are similar to those on *Beipiaosaurus*.

To date, there are nearly *fifty* genera of non-avian dinosaurs that are known to have possessed feathers or feather-like filaments, most of them theropods (Barrett et al. 2015). In many cases, such as *Microraptor* and *Serikornis*, preservation conditions allowed the feathers themselves to be preserved as fossils. While this is not always the case, features like quill knobs and pygostyles have proven to be reliable indicators of feathers being present.

4. Baraminology Introduction

The great variety of feathered dinosaurs provokes us to ponder

how many created kinds might exist among them. There are easily recognizable groups within the non-avian feathered dinosaurs, members of which appear very similar to one another and obviously distinct from other dinosaurs. Ornithomimosaurs, for instance, all share a common body shape resembling a long-tailed, long-armed ostrich (except for the bizarre *Deinocheirus*). Other instantly recognizable groups include Oviraptorosauria, Therizinosauroidea, Troodontidae, Dromaeosauridae, and Alvarezsauroidea. We suspect that these distinct groups of coelurosaurs will be discontinuous from each other.

Five previous studies have used statistical baraminological methods to discern the relationships of coelurosaurs. In a response to Senter's (2010) attempt to use baraminology to prove birds evolved from dinosaurs, Wood (2011) found evidence of discontinuity between birds and non-avian maniraptorans. Although not discussed heavily in the paper, he also detected discontinuity surrounding Oviraptorosauria, Deinonychosauria, and possibly between Troodontidae + *Buitreraptor* and Dromaeosauridae (without *Buitreraptor*).

Cavanaugh (2011) also reanalyzed the Senter (2010) character matrix, this time using Analysis of Patterns (ANOPA). The 3D ANOPA results revealed three clouds of taxa among coelurosaurs, all of which overlapped slightly. Cavanaugh concluded that all theropods, including *Archaeopteryx*, may be in the same created kind, with *Archaeopteryx* as the ancestor of other theropods rather than their descendant.

Garner et al. (2013) analyzed six datasets including traditional birds and traditional dinosaurs using baraminic distance correlation (BDC) and 3D multidimensional scaling (MDS). The results varied with the datasets, but revealed several patterns. First, discontinuity exists among animals traditionally considered birds. For instance, Ornithurae—the group containing all living birds and some fossil species (e.g., *Ichthyornis*)—showed a tendency to cluster together and away from extinct birds like enantiornithines, *Confuciusornis*, or *Archaeopteryx*. Depending on the dataset, some of these non-ornithuran avialans could be grouped with dromaeosaurid dinosaurs. *Archaeopteryx* most consistently correlated with dromaeosaurids in several of the analyses, but in one analysis appeared to group with avialans. The authors concluded that the use of dromaeosaurids as a composite taxon could skew the results, but that *Archaeopteryx* might have been a dromaeosaurid.

Finally, Aaron (2014b) analyzed several different datasets of tyrannosauroids with statistical baraminology and concluded that Tyrannosauridae + some non-tyrannosaurid tyrannosauroids (*Appalachiosaurus*, *Dryptosaurus*, *Raptorex*, *Xiongguanlong*, and *Eotyrannus*) probably constitute a holobaramin, to the exclusion of other “basal” tyrannosauroids such as *Dilong* and *Guanlong*.

METHODS

In order to detect discontinuity among feathered dinosaurs, we used statistical baraminological methods on five different coelurosaur datasets: 1) Brusatte et al. (2014) (modified by Cau et al. (2015)), which is an updated version of the coelurosaur dataset of Turner et al. (2012); 2) Lee et al. (2014a) (modified by Cau et al. (2015)), which is an updated version of the coelurosaur dataset of Godefroit, et al. (2013); 3) van der Reest and Currie (2017), a paravian-heavy



Figure 10. Feathered manus of *Sinornithosaurus*, a dromaeosaurid. Photograph by Paul Garner and used with permission.



Figure 11. *Microraptor* and “*Tetrapteryx*”. **Top:** Full skeleton of the holotype of *Microraptor gui*. Photograph by Paul Garner and used with permission. **Left:** Right manus of the same specimen showing details of the feathers. Modified from photograph by Paul Garner and used with permission. **Right:** William Beebe’s 1915 drawing of the hypothetical “*Tetrapteryx*.” Public Domain.

dataset updated from Gao et al. (2012); 4) Zanno (2010), which was a therizinosaur-heavy update of the Turner et al. (2007a) dataset; and 5) Lamanna et al. (2014), a dataset focusing on oviraptorosaurs updated from Longrich et al. (2013). Statistical baraminological analysis of these datasets was conducted through BDISTMDS (Wood 2008). A 0.75 character relevance cutoff (CRC) was used in all cases. All results were visualized through baraminic distance correlation (BDC) and 3D multidimensional scaling (MDS). In general, we tried to retain as many taxa as possible in the analyses while still keeping at least 100 characters (although we ran Zanno (2010) with 85 characters). This decision resulted in varying taxic relevance cutoff (TRC) values from analysis to analysis (Table 1). We added the basal therizinosaur *Jianchangosaurus* to the Zanno (2010) matrix as coded by Pu et al. (2013).

RESULTS

1. Brusatte et al. (2014) Results

The first attempt at analyzing the Brusatte et al. (2014) dataset resulted in poor resolution for discontinuities within non-avian Coelurosauria (Fig. 17). The BDC shows one large block of positive correlation containing the non-avian coelurosaurs and a second smaller block of positive correlation containing the six extant bird taxa (*Anas*, *Chauna*, *Crax*, *Gallus*, *Crypturellus*, and *Lithornis*), *Apsaravis*, *Hesperornis*, and *Ichthyornis*. Most of these taxa also shared positive correlation with the more “basal” avialans in the analysis (e.g., *Saperornis*, *Jeholornis*, and *Confuciusornis*). These “basal” avialans share positive correlation with non-avian paravian taxa, and some of the “basal” avialans even share positive correlation with non-paravian coelurosaurs. The block containing modern birds shares negative correlation with almost every non-

avian coelurosaurs in the analysis. The 3D MDS results (Fig. 18) show avialan taxa clustered toward the top, and an especially tight cluster near the top of the figure corresponds to the smaller bird block of positive correlation from the BDC.

We suspected that the modern bird + *Apsaravis* + *Ichthyornis* + *Hesperornis* block of taxa was so different from the rest of the coelurosaurs, that its presence was masking evidence for discontinuities among the non-avian coelurosaurs; so, we removed this block of taxa from the analysis and ran it again, a technique commonly used in statistical baraminological analyses (e.g., Aaron 2014a; 2014b; Garner 2016; Wood 2005; Wood 2011). After removing these taxa, the new analysis included 124 characters and 64 taxa. Four main blocks of positive correlation are evident in the BDC (Fig. 19): 1) Tyrannosauroidae, 2) Oviraptorosauria + Therizinosauroidae, 3) Basal Coelurosauria + Ornithomimosauria + Alvarezsauridae, and 4) Paraves.

Analysis of just the Paraves block (100 characters, 23 taxa) resulted in two main blocks of positive correlation in the BDC (Fig. 20): 1) avialans and 2) a Dromaeosauridae + Troodontidae + *Archaeopteryx* block (although there is some positive correlation between *Archaeopteryx* + *Balaurodon* and *Sapeornis* + *Confuciusornis*). The MDS results (Fig. 21) are difficult to interpret. *Balaurodon* and *Zanabazar* are both positioned far away from the other taxa in multidimensional space.

We decided to analyze the tyrannosauroids and basal coelurosaurs together (164 characters, 21 taxa, 0.25 TRC) since there is positive correlation between these blocks in the second Brusatte et al. (2014) analysis. The BDC (Fig. 22) shows three blocks of

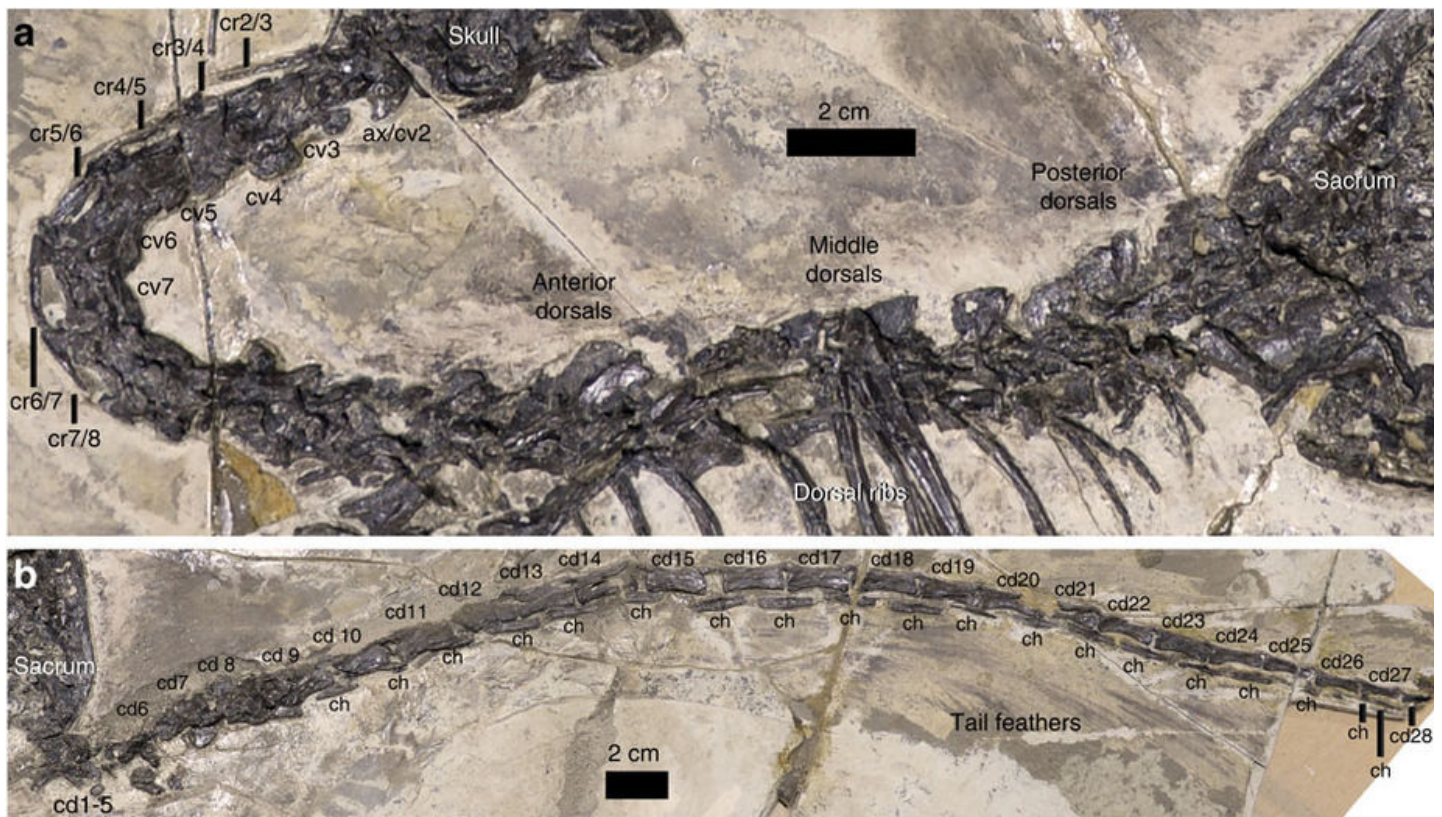


Figure 12. Vertebral column of *Jianianhualong tengi*. a) Neck and torso; b) tail with obvious feathers. From Xu et al. (2017), obtained via Wikimedia Commons. CC BY 4.0.

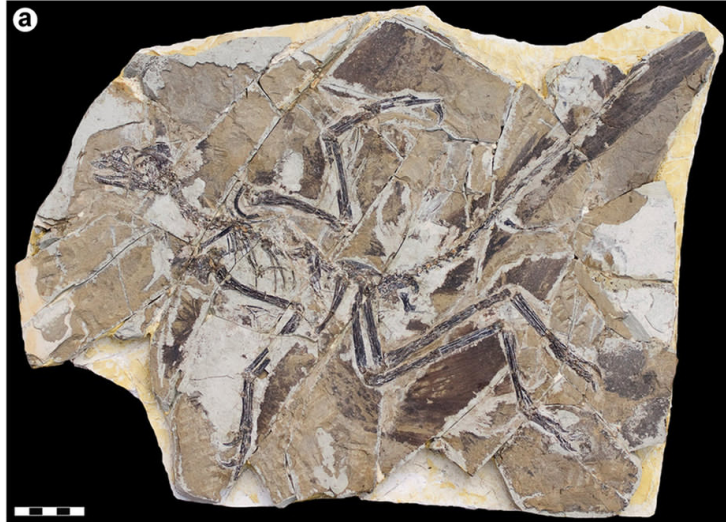


Figure 13: One of the hundreds of specimens of *Anchiornis huxleyi*. Modified from Lindgren et al. (2015), obtained via Wikimedia. CC BY 4.0.



Figure 14. Accurate, 3D-printed cast of the holotype of *Yi qi*. Photograph by Paul Garner.



Figure 15: *Psittacosaurus* with preserved integument. Cropped from Vinther et al. (2016), obtained via Wikimedia Commons. CC BY 4.0.

Table 1. Data on the Baraminological Analyses

Source	Taxa		Characters		Cutoffs	
	Original	Remaining	Original	Remaining	Character Relevance	Taxic Relevance
Brusatte et al. (2014)	860	107/124*	152	78/69*	0.75	0.3**
Lee et al. (2014)	1549	133/157*	121	59/57*	0.75	0.25
Zanno (2010)	348	85	77	37	0.75	0.4
van der Reest and Currie (2017)	366	117	93	52	0.75	0.4
Lamanna et al. (2014)	230	106	41	15	0.75	0.5

*After removing avian taxa.

**Also excluded *Incisivosaurus*, which did not share enough characters in common with several other taxa to be included in the analysis.



Figure 16. Holotype of *Tianyulong* with filamentous integument. Cropped from photograph by BleachedRice, obtained via Wikimedia Commons. CC BY-SA 4.0.

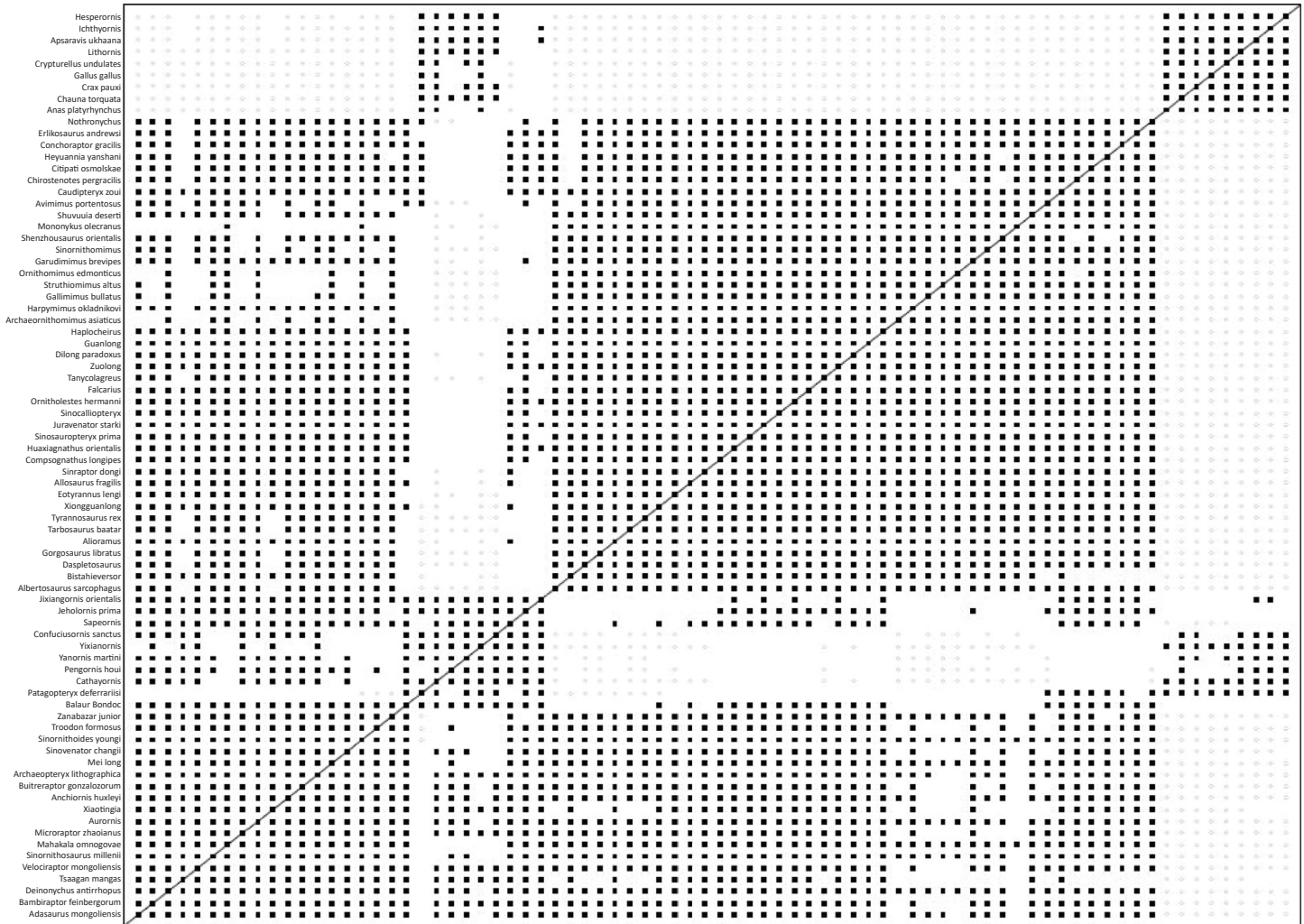
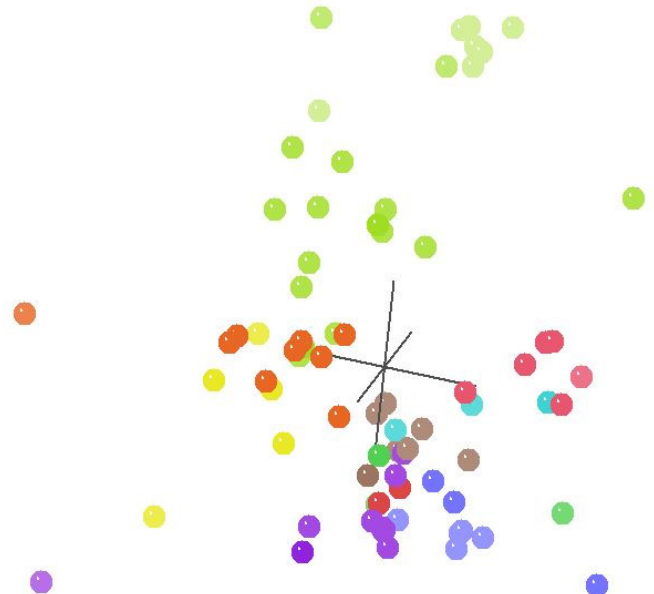


Figure 17 (above). BDC results for analysis of Brusatte et al. (2014) at 0.3 TRC. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

Figure 18 (right). MDS plot of Brusatte et al. (2014) at 0.3 TRC. Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria; turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidae.



positive correlation: 1) derived tyrannosauroids, 2) *Xiongguanlong* and *Eotyrannus*, and 3) “basal” coelurosaurs and some “basal” tyrannosauroids. There is positive correlation between *Xiongguanlong* and *Dilong*, which is in the third block. The 3D MDS (Fig. 23) shows the same three clusters, but they are positioned relatively close to one another. *Bistahieversor* and *Coelurus* are located in unusual spots. We also analyzed a subset of this data for better resolution between “basal” tyrannosauroids and “basal” coelurosaurs, suspecting that the tyrannosaurids may be affecting the observed patterns. This subset included 95 characters and 14 taxa at a 0.25 taxic relevance cutoff (to include as many of these taxa as possible). The BDC results (Fig. 24) show two main blocks of positive correlation separated by negative correlation. One block contains the tyrannosauroids *Appalachiosaurus*, *Xiongguanlong*, and *Eotyrannus*, whereas the other contains the rest of the taxa. Of the larger block of taxa, *Guanlong*, *Dilong*, and *Zuolong* form a distinct block, but *Zuolong* is also continuous with the larger block of “basal” coelurosaurs. The 3D MDS results (Fig. 25) show clear separation between the small cluster of tyrannosauroids and the other larger cluster.

The next Brusatte et al. (2014) subset dataset analyzed was the

“basal” coelurosaurs, ornithomimosaurs, and alvarezsauroids (101 characters, 26 taxa, 0.2 taxic relevance cutoff (to preserve as many taxa as possible)). The BDC results (Fig. 26) show alvarezsauroids together in a block of positive correlation (except for *Haplocheirus*) and separated from all other taxa by negative correlation. The remaining taxa form two blocks of positive correlation, one corresponding to mainly ornithomimosaurs and one to mainly “basal” coelurosaurs. The MDS results (Fig. 27) show a tight clustering of the ornithomimosaurs and “basal” coelurosaurs surrounded by a diffuse cloud of alvarezsauroids. The combination of the BDC and MDS results led us to suspect that removal of the alvarezsauroids from the analysis would probably result in greater resolution for the remaining taxa. The new analysis excluding the alvarezsauroids (107 characters, 23 taxa, 0.2 taxic relevance cutoff) resulted in a BDC (Fig. 28) with two major blocks of positive correlation that share only negative correlation with each other. One block was Ornithomimosauria, and the other block was “basal” coelurosaurs and *Haplocheirus*. *Nqwebasaurus* (a possible “basal” ornithomimosaur) does not correlate with any other taxa in the analysis except *Coelurus*, and *Coelurus* correlates positively with some “basal” coelurosaurs. The 3D MDS results

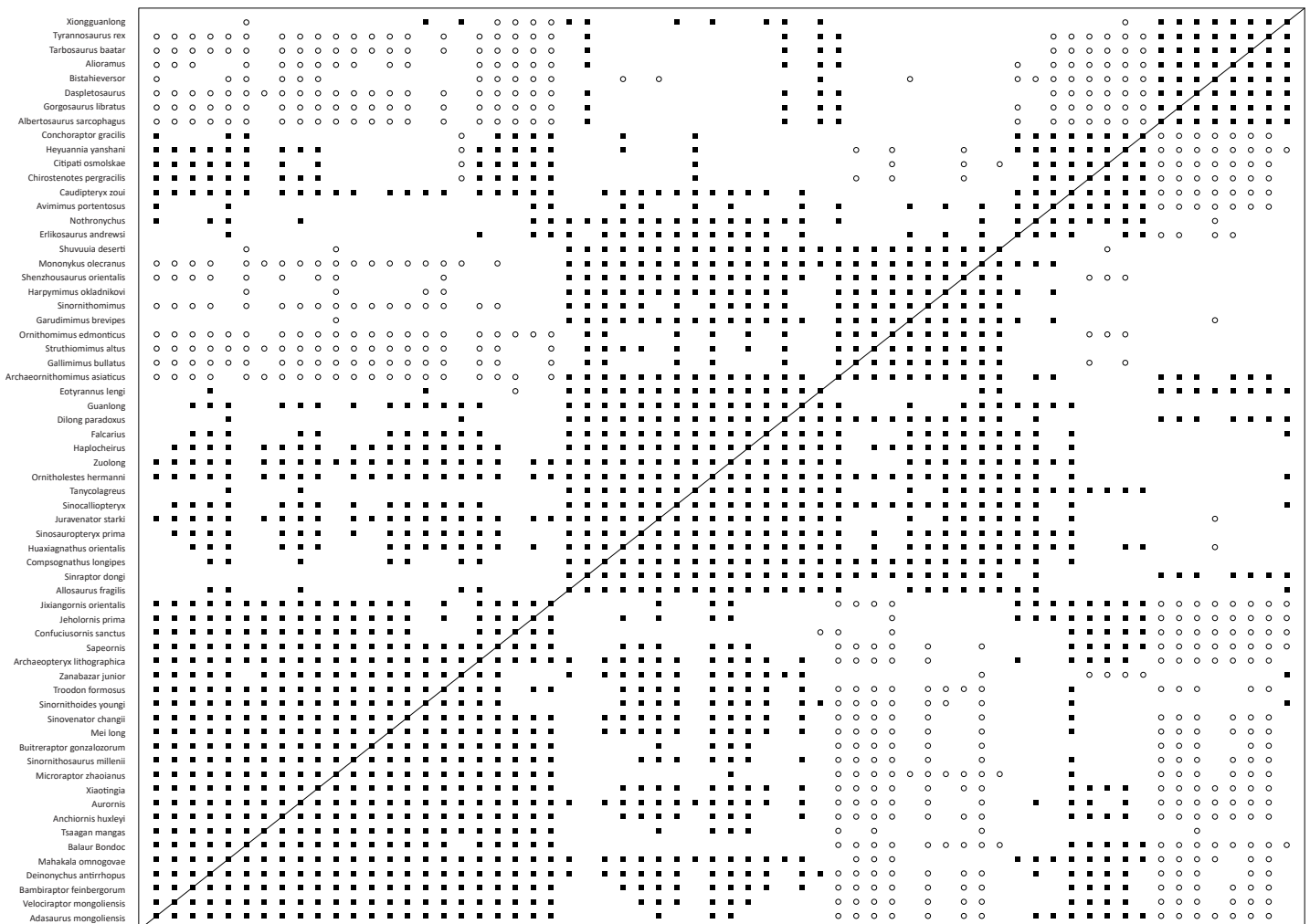


Figure 19. BDC results for subset analysis of Brusatte et al. (2014) missing the definite birds. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

(Fig. 29) show two clusters, corresponding to the two main blocks of positive correlation from the BDC, with *Coelurus* and *Nqwebasaurus* situated between the two clusters.

The final subset of the Brusatte et al. (2014) dataset we analyzed consisted of therizinosauroid and oviraptorosaur taxa (10 taxa, 68 characters, 0.3 taxic relevance cutoff). We wanted to include more taxa, but to get more than 50 characters, we had to exclude all but 3 therizinosauroids. The BDC (Fig. 30) shows one large cluster of positive correlation corresponding to Oviraptorosauria, except for the oviraptorosaur *Incisivosaurus*, which did not correlate with any other taxa. The therizinosaurids *Erlikosaurus* and *Nothronychus* share positive correlation, and the “basal” therizinosaur *Falcarius* did not share positive correlation with any of the taxa in the analysis. Some negative correlation can be found between *Erlikosaurus* and several oviraptorosaurs and between *Nothronychus* and *Avimimus*. Removal of *Incisivosaurus* from the analysis makes the characters used jump to 100, but the pattern does not change. The MDS results (Fig. 31) show a similar result to the BDC, however it is worth noting that the taxon closest to the loosely clustered therizinosaurids is the “basal” therizinosaur *Falcarius*.

2. Lee et al. (2014) Results

We ran the Lee et al (2014) dataset at a 0.25 taxic relevance cutoff initially including the birds *Meleagris* and *Ichthyornis* (BDC results in Appendix), but we then excluded these taxa as we suspected they were masking the evidences of continuity and discontinuity among the non-avian coelurosaurs. The BDC (Fig. 32) shows two main blocks of positive correlation: Pennaraptora and the rest of the theropods. The 3D MDS results (Fig. 33) show an undecipherable shotgun blast pattern. As with the Brusatte et al. (2014) analysis, we determined to analyze each block separately.

The BDC results (Fig. 34) for the Pennaraptora subset (263 characters, 18 taxa, 0.25 taxic relevance cutoff) show four main blocks of positive correlation. One block corresponded to oviraptorosaurs, another to avialans, another to some

dromaeosaurids, and another to troodontids + *Archaeopteryx* + some dromaeosaurids. *Archaeopteryx* also shares positive correlation with some avialans. The MDS results (Fig. 35) show four main clusters of taxa, corresponding to the four blocks of positive correlation in the BDC, separated from each other by gaps in morphological space. The oviraptorosaurs are the farthest removed cluster. Although *Archaeopteryx* is located between the avialan and dromaeosaurid clusters, it is closer to the dromaeosaurids. The three dromaeosaurid taxa (*Achillobator*, *Velociraptor*, and *Deinonychus*) that were not positively correlated with the other dromaeosaurids in the BDC are also separated from the other dromaeosaurids in the 3D MDS results. As oviraptorosaurs are obviously different from the rest of the taxa, we determined to drop them and run a strictly paravian dataset (277 characters, 14 taxa, 0.25 TRC). There are three major blocks of positive correlation corresponding to the blocks from the pennaraptoran analysis (Fig. 36). The main difference is that *Archaeopteryx* does not correlate with any other taxa, except some negative correlation with the dromaeosaurids *Deinonychus* and *Achillobator*. The MDS results (Fig. 37) were similar to those obtained for Pennaraptora (Fig. 32) except for the absence of oviraptorosaurs.

We also analyzed the remaining non-pennaraptoran taxa from the Lee et al. (2014) dataset using BDISTMDS (164 characters, 38 taxa, 0.25 taxic relevance cutoff). The BDC results (Fig. 38) show two major blocks of positive correlation. One block is made of tyrannosauroids and non-coelurosaurs, and the other contains the non-tyrannosauroid coelurosaurs. Alvarezsaurids and the therizinosaurid *Erlikosaurus* do not correlate positively with many other taxa in the BDC. Additionally, the ceratosaurs *Majungasaurus*, *Limusaurus*, and *Masiakasaurus* correlate positively with each other and with very few other taxa in the BDC. Oddly, herrerasaurids group well with the basal coelurosaurs. The MDS results (Fig. 39) show three big clusters of taxa: 1) Ornithomimosauria, 2) “basal” coelurosaurs + Herrerasauridae + *Cryolophosaurus* + *Falcarius* + *Haplocheirus* + *Dilong* + *Guanlong*, and 3) non-coelurosaurs + *Tyrannosaurus* + *Yutyrannus*. Scattered around the three clusters

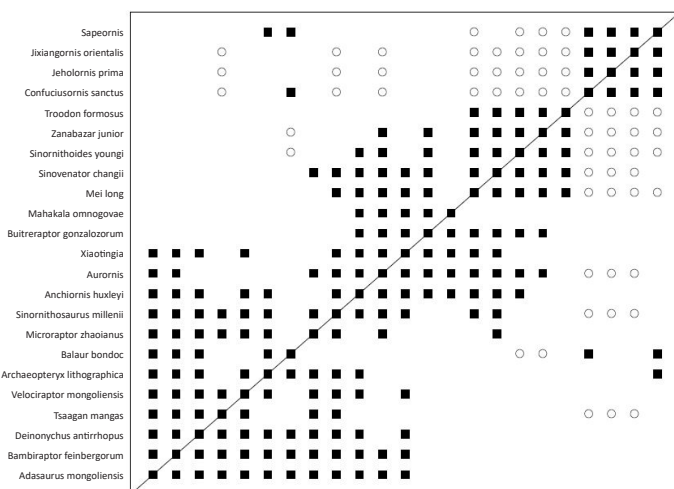


Figure 20. BDC plot of the Paraves subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

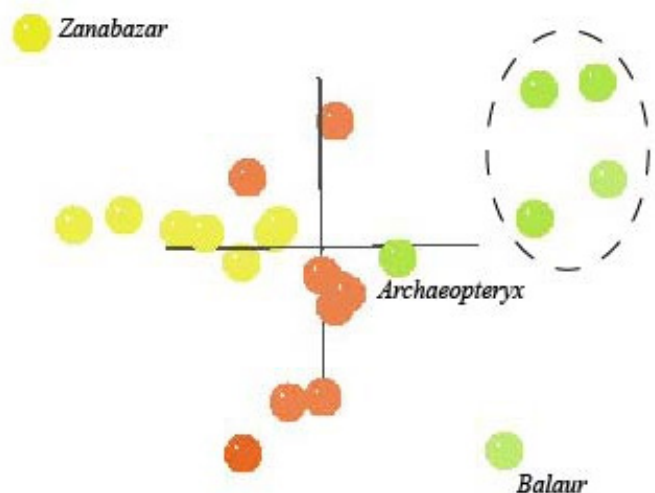


Figure 21. MDS results for the Paraves subset of the Brusatte et al. (2014) dataset. The four taxa that form a small block of positive correlation in the BDC of Figure 26 cluster together here and are circled. Colors: orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae.

at some distance are the alvarezsaurids, *Erlikosaurus*, and some non-tetanuran taxa (“*Syntarsus*” *kayentakatae*, *Limusaurus*, *Masiakasaurus*, and *Majungasaurus*). These BDC and MDS results made us suspect that the large amount of very disparate taxa are masking discontinuity. Thus, we reanalyzed two subsets of this dataset: 1) non-coelurosaurs + Tyrannosauroida and 2) non-pennaraptoran coelurosaurs.

The BDC (Fig. 40) for the Tyrannosauroida + non-coelurosaur subset of taxa (333 characters, 20 taxa, 0.25 TRC) is split up into five blocks of positive correlation and the abelisaurid *Majungasaurus*, which correlates with no other taxa. There are two blocks of two taxa each: 1) ceratosaurs *Limusaurus* and *Masiakasaurus* and 2) *Tawa* and *Herrerasaurus*. Another block of positive correlation contains three coelophysoid-grade theropods: *Dilophosaurus*, “*Syntarsus*” *kayentakatae*, and *Cryolophosaurus* (although *Cryolophosaurus* may be a tetanuran (Carrano et al. 2012)). The next block of taxa

contains the tyrannosauroids, but *Yutyrannus* and *Tyrannosaurus* share positive correlation with *Allosaurus* in the large block. The large block contains an assortment of non-coelurosaur tetanurans and *Ceratops*. In general, the 3D MDS results (Fig. 41) are similar to the BDC results, showing *Majungasaurus* by itself, and then two main clusters, a diffuse cluster containing all of the herrerasaurids and more “basal” theropods and a second cluster made up of two smaller clusters, one corresponding to tyrannosauroids and the other to the remaining taxa.

Concerning the non-pennaraptoran coelurosaur taxa from the Lee et al. (2014) dataset, the subset (189 characters, 22 taxa, 0.25 TRC) BDC (Fig. 42) shows a block of positive correlation containing the two alvarezsaurid taxa, which share negative correlation or no correlation with every other taxon in the BDC. The therizinosaurid *Erlikosaurus* does not correlate with any other taxa except negatively with *Yutyrannus* and *Tyrannosaurus*. The

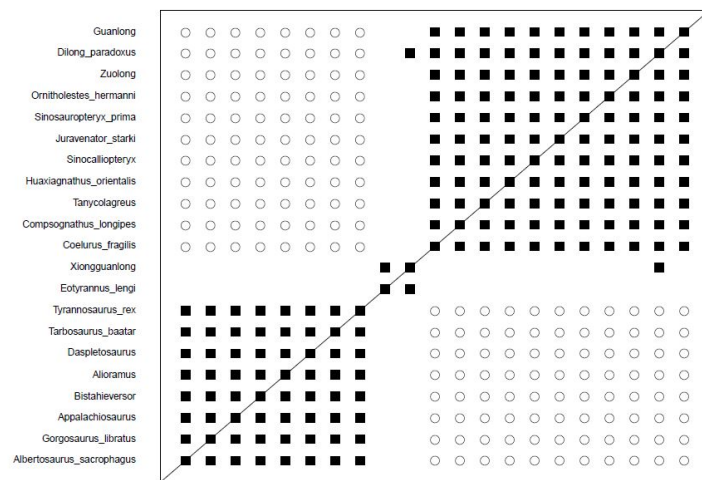


Figure 22. BDC results for the Tyrannosauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

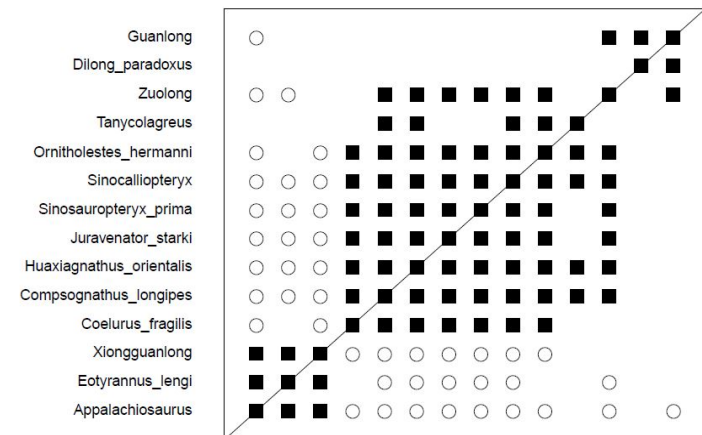


Figure 24. BDC results for the “basal” Tyrannosauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

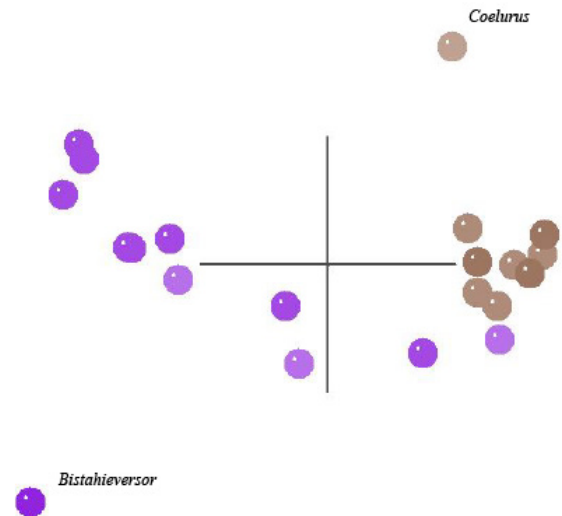


Figure 23: MDS results for the Tyrannosauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Colors: brown – “basal” Coelurosauria; purple – Tyrannosauroida.

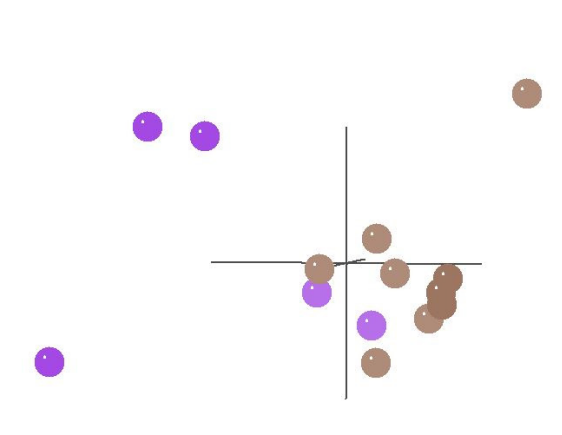


Figure 25: MDS results for the “basal” Tyrannosauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Colors: brown – “basal” Coelurosauria; purple – Tyrannosauroida.

remaining taxa show no negative correlation between them, but there are still distinct blocks of positive correlation corresponding to 1) *Tyrannosaurus* + *Yutyrannus*, 2) the ornithomimosaurs (minus *Nqwebasaurus*), and 3) the rest of the taxa. The 3D MDS results (Fig. 43) show the two alvarezsaurids and *Erlikosaurus* as separate from the rest of the taxa and each other. The remaining taxa fall into three groups, ornithomimosaurs on one end, the tyrannosauroids *Tyrannosaurus* and *Yutyrannus* (spaced far from each other) on the other end, and the rest of the taxa in the middle cluster. We determined to remove the alvarezsaurids and *Erlikosaurus* to better understand the relationships between the remaining taxa.

The final subset analysis (226 characters, 19 taxa, 0.25 TRC) of Lee et al. (2014) contained non-maniraptoran coelurosaurs, *Falcarius*, and *Haplocheirus*. The BDC results (Fig. 44) show two major blocks of positive correlation. All of the ornithomimosaurs share positive correlation with each other, and they share either

negative correlation or no correlation with the other taxa in the analysis. *Tyrannosaurus*, *Yutyrannus*, and *Nqwebasaurus* each share no correlation with any other taxa, except for *Tyrannosaurus* and *Yutyrannus* sharing some negative correlation with the ornithomimids. The remaining taxa show some evidence of shared positive correlation, but certain taxa like the “basal” therizinosaur *Falcarius* and the “basal” alvarezsauroid *Haplocheirus* have very few connections to the other taxa in the analysis. The MDS results (Fig. 45) show a separate ornithomimosaur cluster, and *Tyrannosaurus* and *Yutyrannus* are far removed from all of the other taxa, too. The remaining central cluster shows gaps between smaller sub-clusters, which matches the loose positive correlation visible in the BDC. We did analyze these taxa separately, and the results are in the Appendix (Figs 70-71).

3. Zanno (2010) Results

Analysis of the Zanno (2010) dataset at a 0.4 TRC resulted in the

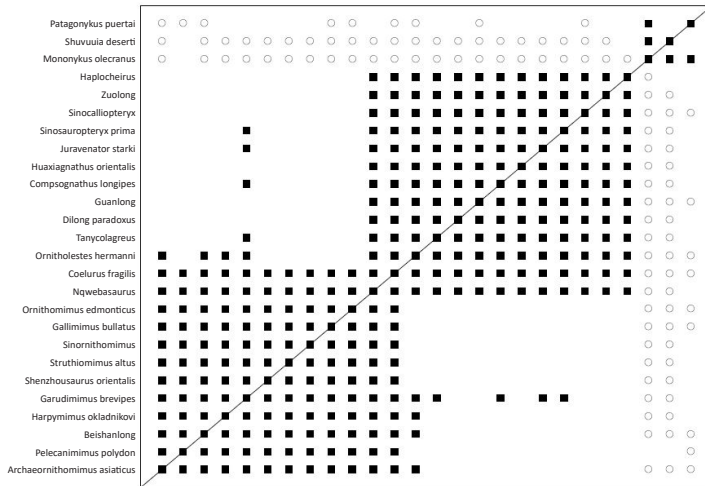


Figure 26. BDC results of the Ornithomimosauria + Alvarezsauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

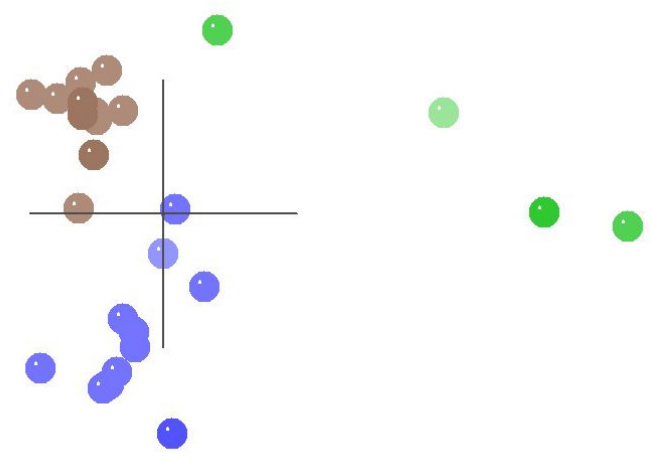


Figure 27. MDS results for the Ornithomimosauria + Alvarezsauroida + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Colors: green – Alvarezsauroida; blue – Ornithomimosauria; brown – “basal” Coelurosauria.

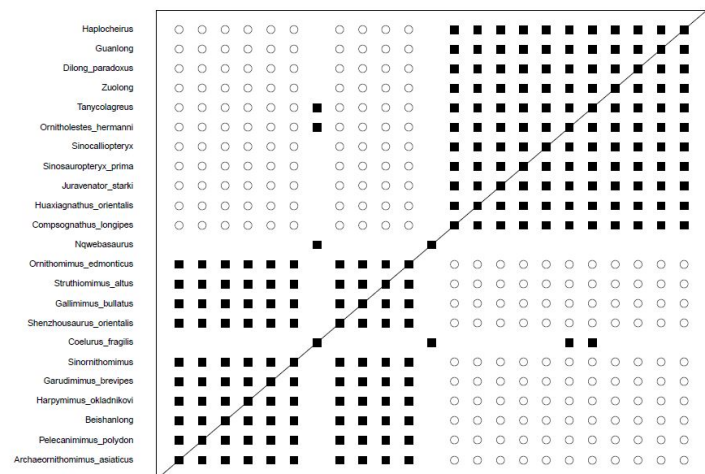


Figure 28. BDC results of the Ornithomimosauria + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

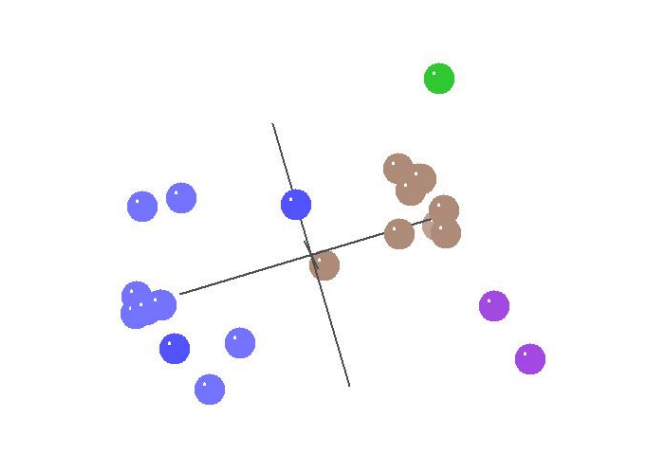


Figure 29. MDS results of the Ornithomimosauria + “basal” Coelurosauria subset of the Brusatte et al. (2014) dataset. Colors: green – Alvarezsauroida; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroida.

inclusion of 37 taxa and 85 characters, which is a small representation of the original 348 characters. The BDC (Fig. 46) shows four distinct blocks of positive correlation: 1) Therizinosauridae (2 taxa), 2) Paraves, 3) Oviraptorosauria, and 4) the rest of the taxa. The therizinosaurid block shares either negative correlation or no correlation with any of the other taxa in the analysis. The paravian block has only a few instances of shared positive correlation with the oviraptorosaur block, but the rest of the pairings are either negative correlations or no correlations. The oviraptorosaur block also shares some positive correlations with some ornithomimosaur taxa from the block of remaining taxa. The 3D MDS results (Fig. 47) show four clusters of taxa separated by gaps in morphological space. The two therizinosaurid taxa are widely separated from the remaining taxa. Of the remaining taxa, three clusters are obvious: 1) Paraves, 2) Oviraptorosauria, and 3) the remaining taxa. As a result, we determined to analyze each of these blocks separately with BDC and 3D MDS.

BDC analysis of the paravian subset of Zanno (2010) (121 characters, 12 taxa, 0.39 TRC (the TRC was lowered to include *Troodon*)) resulted in two blocks of positive correlation that share no correlation of any kind between each other (Fig. 48). One block contains dromaeosaurids, and the other contains troodontids. *Archaeopteryx*, *Confuciusornis*, and *Buitreraptor* do not share any kind of correlation with any other taxa, except that *Confuciusornis* shares negative correlation with two troodontids. The 3D MDS results (Fig. 49) show *Archaeopteryx* and *Confuciusornis* far away from the other taxa. *Buitreraptor* is clustered closely with the other dromaeosaurids, and there is space between the dromaeosaurid and troodontid clusters. The troodontids are split into two pairs of taxa: 1) *Mei* and *Sinovenator*, and 2) *Sinornithoides* and *Troodon*.

The oviraptorosaur subset (68 characters, 15 taxa, and 0.3 TRC (we lowered the TRC to include more oviraptorosaurs that we could not include in the full analysis)) contains 8 oviraptorosaur taxa and

seven outgroup taxa (one therizinosaur, three ornithomimosaur, and three paravians). The BDC results show three large blocks of positive correlation that are unconnected by any other correlation (Fig. 50): 1) Oviraptorosauria, 2) Paraves + *Falcarius*, and 3) Ornithomimosauria. The oviraptorosaur *Incisivosaurus* does not positively correlate with any taxa in the analysis, but it does share negative correlation with the ornithomimosaur. The 3D MDS (Fig. 51) shows *Incisivosaurus* far away from all other taxa. Additionally, there are three clusters of taxa corresponding to the three blocks of positive correlation from the BDC. Within the oviraptorosaur cluster, *Avimimus* + *Chirostenotes* are somewhat removed from the other taxa.

Most therizinosaurid species are only known from fragmentary specimens. Most of the other analyses we conducted only featured two or three therizinosaur taxa. The Zanno (2010) matrix contains the best dataset for therizinosaur, so we lowered the TRC to 0.3 to include as many taxa as possible and still have over 50 characters (62 characters, 16 taxa: eight therizosaurs and eight outgroup taxa). The BDC results show three major blocks of positive correlation (Fig. 52). Therizinosaurids along with “basal” therizinosauroids *Alxasaurus* and *Beipiaosaurus* make up the bottom block of taxa. In addition, the “basal” therizinosaur *Jianchangosaurus* shares positive correlation with *Beipiaosaurus*. *Falcarius*, however, does not share positive correlation with any other therizinosaur, and it actually shares negative correlation with several forms. Instead, it shares positive correlation with the oviraptorosaur block and *Garudimimus*, which is in the ornithomimosaur block. The caenagnathid oviraptorosaur *Chirostenotes* also shares positive correlation with *Garudimimus*. The 3D MDS results (Fig. 53) are intriguing in that the therizosaurs (to the exclusion of *Falcarius*) form a trajectory with *Jianchangosaurus* on one end and *Segnosaurus* on the other. *Falcarius* is off by itself, but closest to the oviraptorosaur cluster.

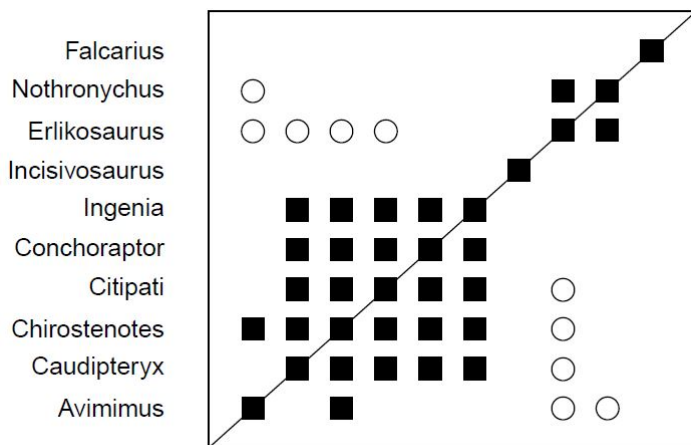


Figure 30. BDC results for the Therizinosauria + Oviraptorosauria subset of the Brusatte et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

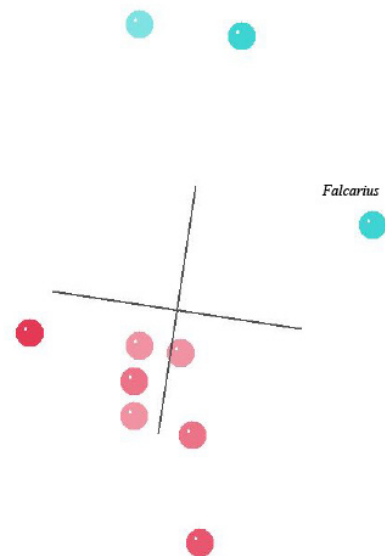


Figure 31. MDS results of the Therizinosauria + Oviraptorosauria subset of the Brusatte et al. (2014) dataset. Colors: pink – Oviraptorosauria; turquoise – Therizinosauria.

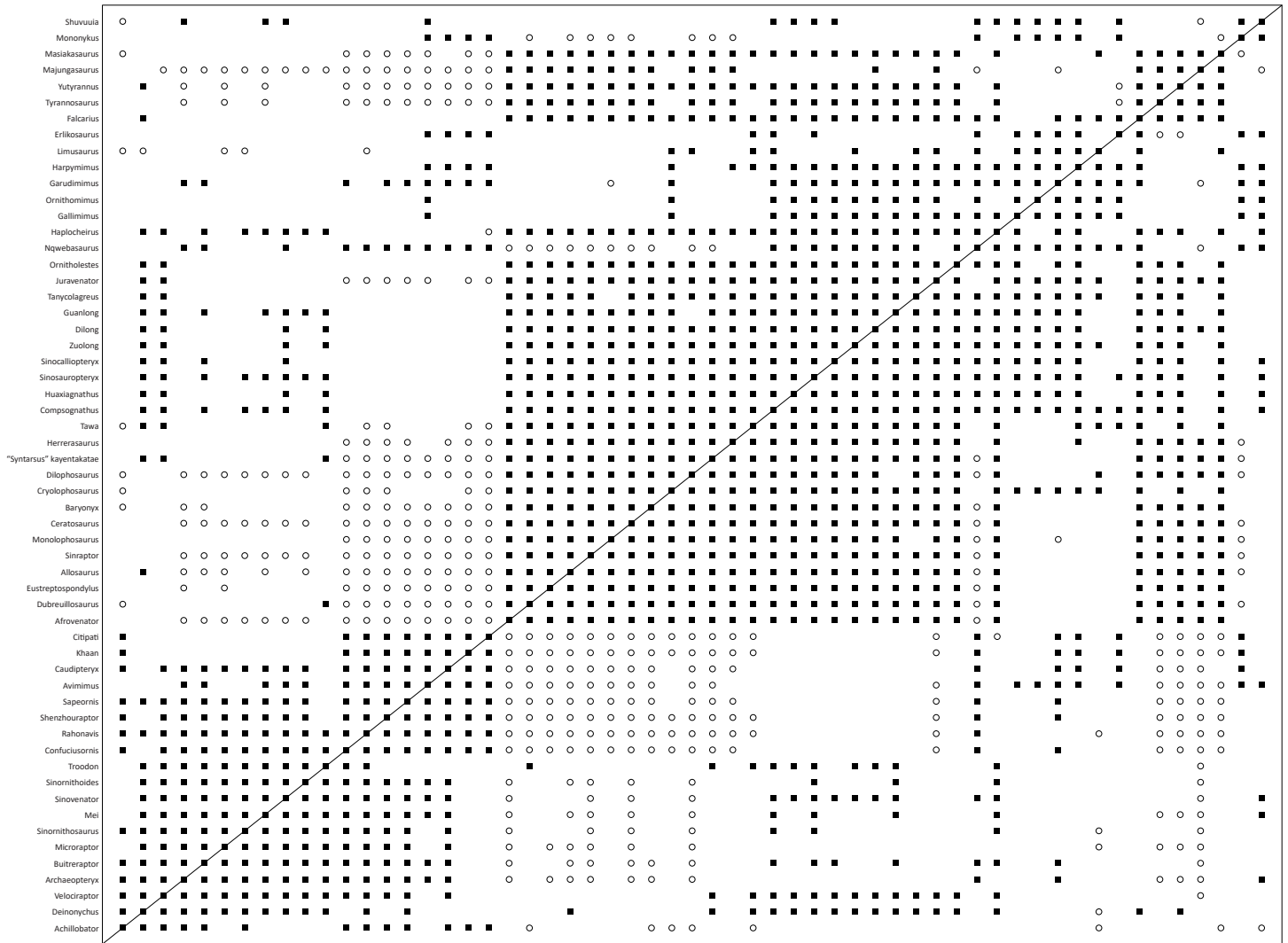
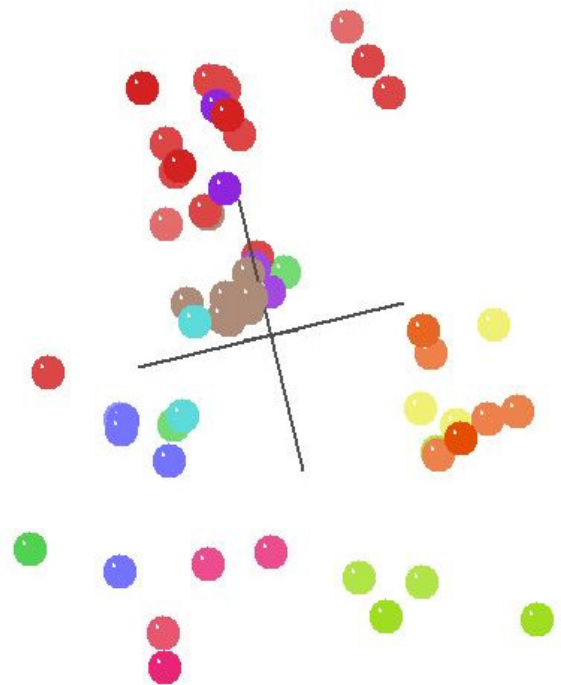


Figure 32 (above): BDC results of the Lee et al. (2014) analysis. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

Figure 33 (right): MDS results for the Lee et al. (2014) analysis lacking definite birds. Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria; turquoise – Therizinosauria; green – Alvarezsauridae; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauridae.



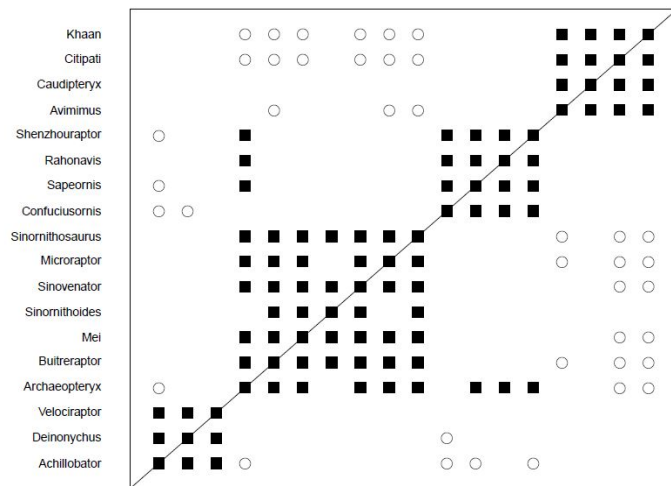


Figure 34. BDC results for the Pennaraptora subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

The final subset dataset of Zanno (2010) contained the rest of the taxa (138 characters, 16 taxa, 0.4 TRC). The BDC results (Fig. 54) show three main blocks of positive correlation: 1) Alvarezsauridae, 2) Ornithomimosauria, and 3) the rest of the taxa. The two alvarezsaurid taxa share no correlation or negative correlation with all other taxa in the subset analysis, and the same is true for the ornithomimosaur block of taxa. The 3D MDS results (Fig. 55) show three obvious clusters separated by gaps in morphological space: 1) Alvarezsauridae, 2) Ornithomimosauria, and 3) the rest of the taxa. Among the ornithomimosaur taxa, *Garudimimus* and *Archaeornithomimus* are the farthest away from the others. The remaining taxa have tyrannosaurids on one end, and then a triangle of taxa marked at the corners by *Allosaurus*, *Ornitholestes*, and *Dilong*.

4. Van der Reest and Currie (2017) Results

The BDC results (Fig. 56) for the van der Reest and Currie (2017) dataset analysis show three main blocks of positive correlation: 1) Oviraptorosauria, 2) Paraves, and 3) the rest of the taxa. The oviraptorosaur and paravian blocks share positive correlation mainly around the two scansoriopterygid taxa (*Epidendrosaurus* (junior synonym of *Scansoriopteryx*) and *Epidexipteryx*). There are no instances of negative correlation between the oviraptorosaur and paravian blocks. However, there are numerous instances of negative correlation between the oviraptorosaur + paravian blocks and the block containing the rest of the taxa. Shared positive correlation between the oviraptorosaur + paravian blocks and the third block center around the taxa *Protarchaeopteryx*, *Ornitholestes*, *Dilong*, *Falcarius*, and *Pelecanimimus*. The 3D MDS results (Fig. 57) show a single large cluster, although three main lobes can be discerned that correlate with the three blocks of positive correlation from the BDC. *Pelecanimimus* is not clustered with any other taxa in the MDS results. As with the other analyses, we determined to separately analyze subsets of the van der Reest and Currie (2017) dataset for better resolution of patterns of continuity and discontinuity.

The subset analysis of the paravian taxa from the van der Reest

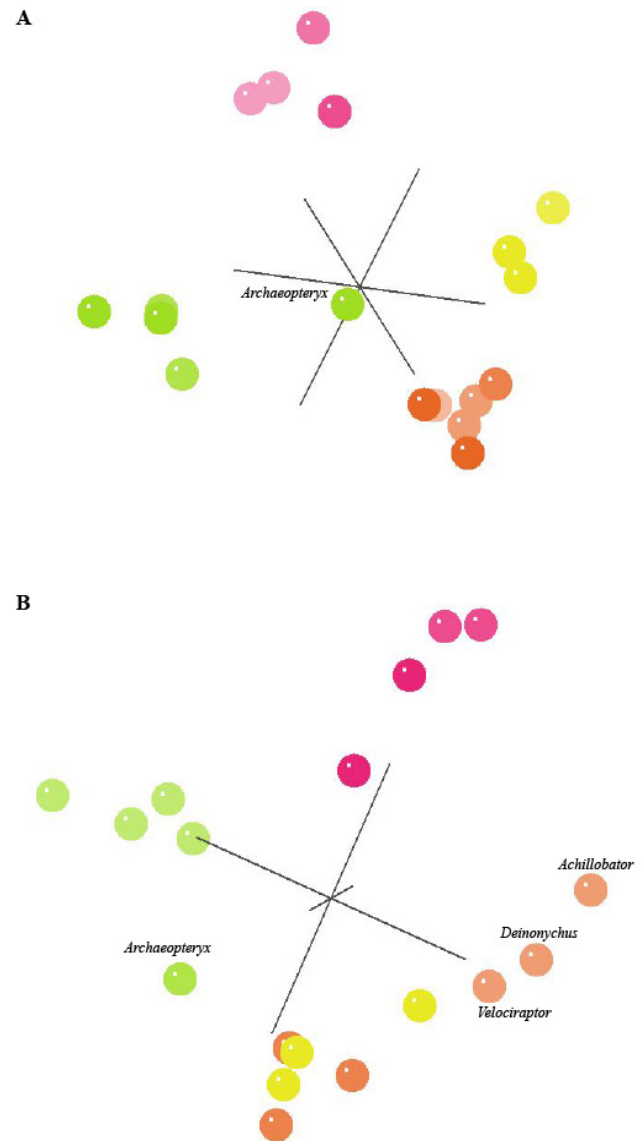


Figure 35. MDS results for the Pennaraptora subset of the Lee et al. (2014) dataset in two views (A, B). Colors: orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria.

and Currie (2017) (119 characters, 22 taxa, 0.4 TRC) BDC results (Fig. 58) show four blocks of positive correlation: 1) Scansoriopterygidae, 2) Avialae, 3) Troodontidae, and 4) Dromaeosauridae. There are instances of shared positive correlation between dromaeosaurid and troodontid taxa. In fact, *Buitreraptor*, an unenlagiine dromaeosaurid, is located in the troodontid block, although it shares positive correlation with some dromaeosaurids (*Velociraptor*, *Deinonychus*, and *Bambiraptor*). *Anchiornis* is in the troodontid block, but it also correlates positively with *Microraptor* and *Sinornithosaurus*. There are no instances of shared positive correlation between the avialan or scansoriopterygid blocks and any other taxa. There are some instances of negative correlation between the scansoriopterygids and some troodontid taxa, and there are many instances of negative correlation shared between avialans and troodontids, with only a few between dromaeosaurids and avialans. The 3D MDS results (Fig. 59) show four obvious clusters

separated by gaps in morphological space; however, *Buitreraptor* does fall in between the troodontid and dromaeosaurid clusters (Fig. 59B).

We determined to include the scansoriopterygids in the oviraptorosaur analysis since there was shared positive correlation between them and the oviraptorosaurs in the main analysis. Additionally, scansoriopterygids are often near oviraptorosaurs in phylogenies, as is the therizinosauroid *Falcarius*, which we also included as an outgroup. The BDC results (Fig. 60) for this analysis (89 characters, 14 taxa, 0.35 TRC (to include more oviraptorosaur taxa)) show two major blocks of positive correlation: Scansoriopterygidae and Oviraptorosauria. The scansoriopterygids share negative correlation with the oviraptorosaur block of taxa and with *Caudipteryx*, which does not correlate with any other taxa. *Falcarius* and *Protarchaeopteryx* also do not correlate with any other taxa in the analysis. The caenagnathid oviraptorosaur *Chirostenotes* correlates positively with *Citipati* in the oviraptorosaur block, but not with any other taxa in the analysis. The “basal” oviraptorosaur *Avimimus* only correlates positively with *Oviraptor* and negatively with *Epidendrosaurus*. The 3D MDS results (Fig. 61) show the two scansoriopterygid taxa clustered together and both far away from any other taxa in the analysis. The remaining clustering is difficult to interpret. There is definitely a tight cluster of oviraptorosaurs that corresponds to the oviraptorosaur block in the BDC. The closest taxa to this cluster are *Oviraptor*, *Caudipteryx*, and *Chirostenotes*. *Avimimus* is farther away than expected from the BDC results. *Falcarius* and *Protarchaeopteryx* are both far away from the main cluster, but somewhat close to *Caudipteryx* and *Chirostenotes*.

The subset analysis for the rest of the taxa (137 characters, 21 taxa) was analyzed at a 0.4 TRC like the total van der Reest and Currie (2017) analysis. The BDC results (Fig. 62) show three blocks of positive correlation: 1) Alvarezsauridae, 2) Ornithomimosauria, and 3) the rest of the taxa except *Erlikosaurus*, which does not correlate positively with any other taxa in the analysis. The two alvarezsaurids do not correlate positively with any other taxa in the analysis, and they correlate negatively with *Archaeornithomimus* and with many taxa in the large, non-maniraptoriform block.

Several ornithomimosaur taxa correlate negatively with *Allosaurus* and *Sinraptor*, and *Pelecanimimus* and *Ornithomimus* correlate negatively with *Dilong*. *Harpymimus* is the only ornithomimosaur to correlate positively with the large block. The MDS results (Fig. 63) show *Erlikosaurus* far away from all other taxa, and the two alvarezsaurids are close to each other, but separated from the other taxa by a large gap in morphological space. The remaining taxa fall into three separate clusters that make a line in morphological space, except for *Archaeornithomimus*, *Tanycolagreus*, and *Falcarius*, which do not fall into any of the three clusters. The cluster on one end contains the tyrannosauroids and the non-coelurosaurs. The cluster in the middle contains the “basal” coelurosaur taxa. The cluster on the other end contains the ornithomimosaurs, except for *Harpymimus*, which is positioned halfway between the ornithomimosaur cluster and the “basal” coelurosaur cluster.

5. Lamanna et al. (2014) Results

The BDC results (Fig. 64) for the oviraptorosaur matrix used by Lamanna et al. (2014) shows three main blocks of positive correlation. One block, containing the outgroup taxa, correlates negatively with the large oviraptorosaur block of positive correlation. The outgroup taxon *Velociraptor* also correlates negatively with the caenagnathid oviraptorosaur *Anzu*, which does not correlate with any other taxa in the analysis (although when run at a 0.3 TRC, *Anzu* positively correlates with *Gigantoraptor*, which positively correlates with *Conchoraptor* in the oviraptorosaur block (see Appendix, Fig. 74)). *Avimimus* also does not correlate with any other taxa in the analysis. The final block of positive correlation contains two “basal” oviraptorosaurs: *Incisivosaurus* and *Caudipteryx*. The 3D MDS results (Fig. 65) show three clear clusters of taxa, separated from each other by large gaps in morphological space. *Anzu* is not close to any of the clusters. The larger cluster contains the oviraptorids, and then there are two clusters of three taxa each: 1) the outgroup and 2) *Avimimus* + *Caudipteryx* + *Incisivosaurus*.

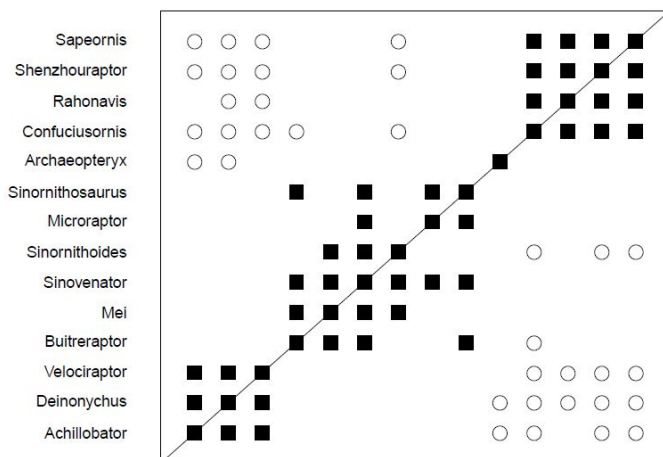


Figure 36. BDC results of the Paraves subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

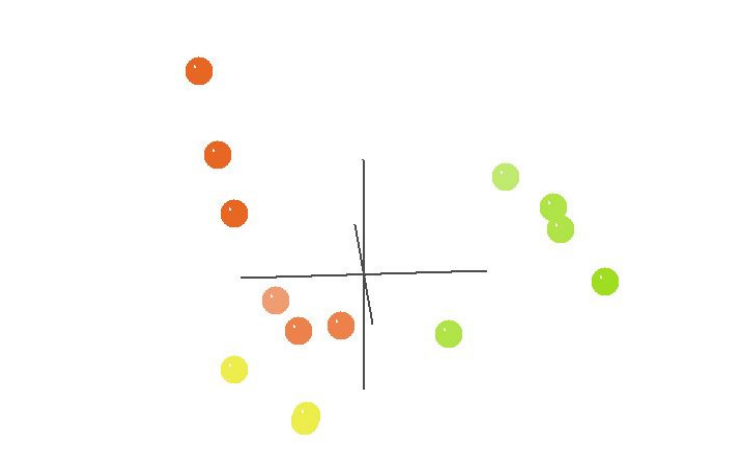


Figure 37. MDS results of the Paraves subset of the Lee et al. (2014) dataset. Colors: orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae.

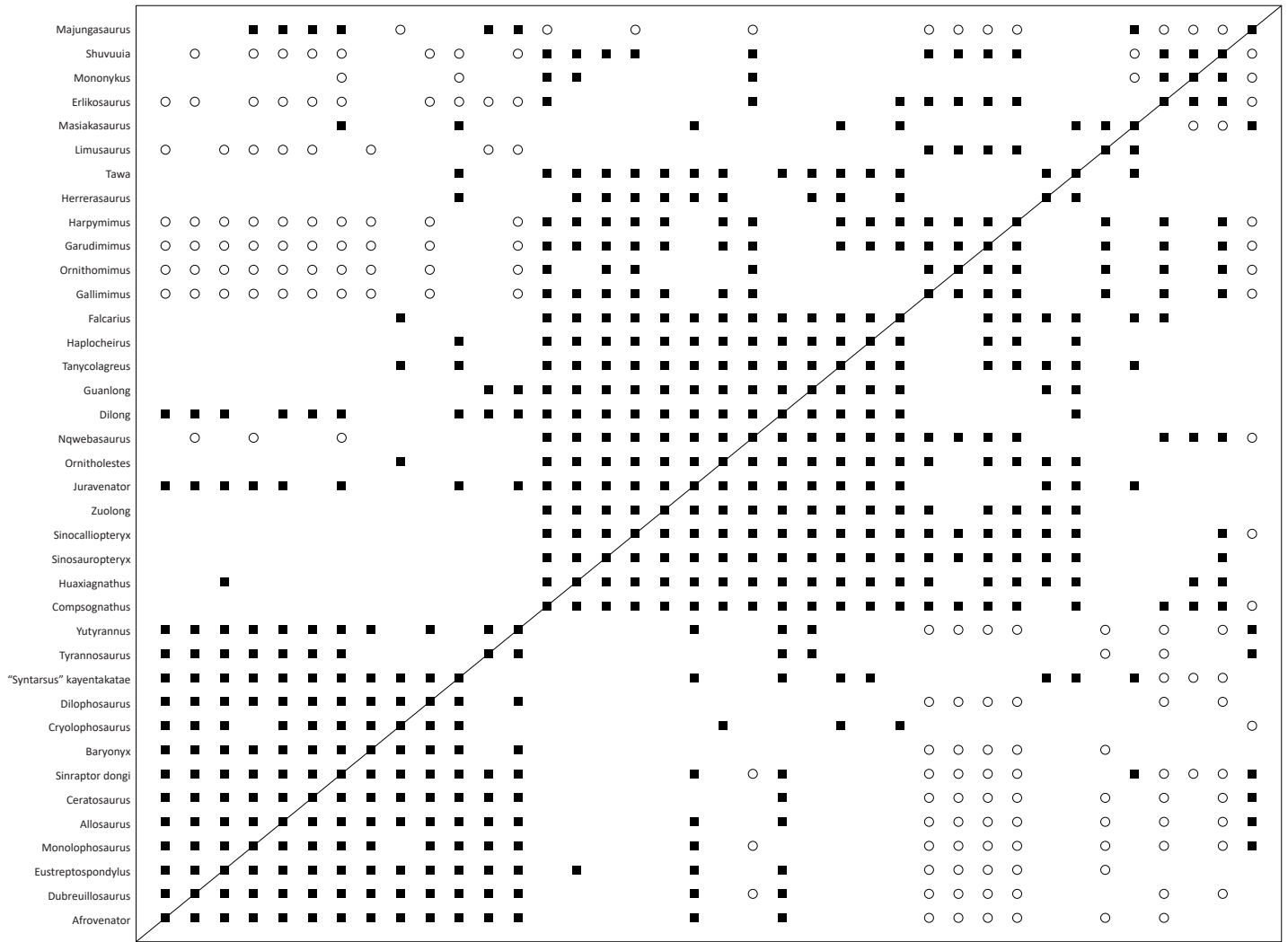


Figure 38. BDC results of the non-pennaraptoran theropod subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

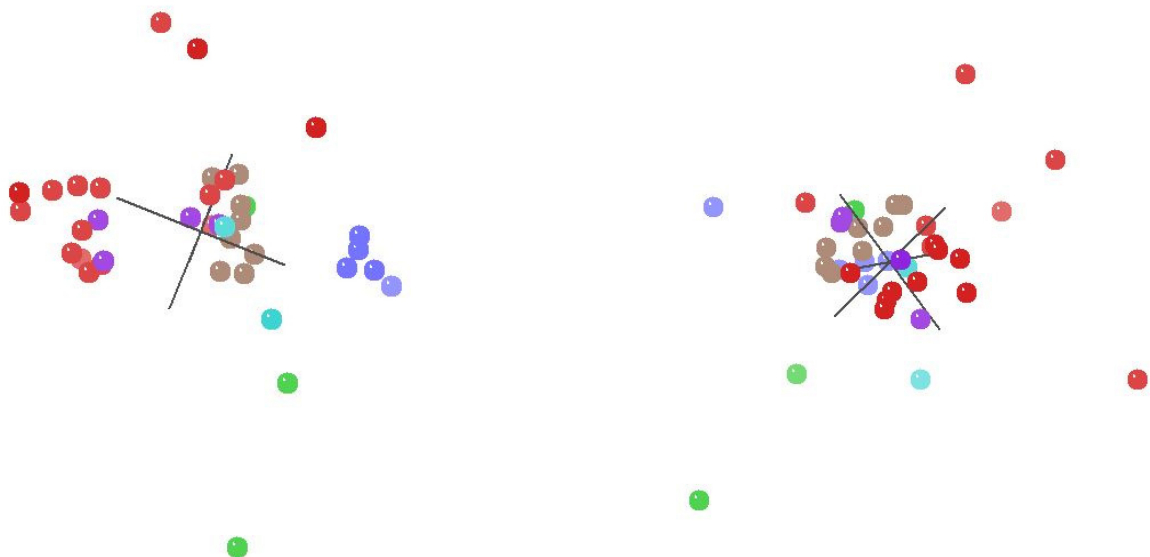


Figure 39. MDS results of the non-pennaraptoran theropod subset of the Lee et al. (2014) dataset in two views (**left** and **right**). Colors: red – non-coelurosaur theropod; turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosaurioidea.

DISCUSSION

1. Baraminology Discussion

Because we analyzed such a large number of datasets and subsets of datasets, the best way to discuss the results of these analyses is to discuss what the results mean for each taxonomic group of interest.

A. *Avialae*

Avialans were included in many of these analyses, and we consistently found evidence of discontinuity separating avialans from other non-avian theropods. Avialans did not correlate positively with dromaeosaurids or troodontids in the paravian subset BDC results for Lee et al. (2014), Zanno (2010), or Van der Reest and Currie (2017) (Figs. 36, 48, and 58, respectively). Additionally, the 3D MDS results in these same analyses show an avialan cluster separate from the other taxa (Figs. 37, 49, and 59, respectively). There are some positive correlations between

Archaeopteryx and deinonychosaurs in the paravian subset analysis of Brusatte et al. (2014) (Fig. 20). Additionally, *Archaeopteryx* and *Balaur* (possibly a dromaeosaurid or a “basal” avialan) correlate positively with some other avialans in this analysis (*Sapeornis* and *Confuciusornis*). *Balaur* is poorly represented (TRC < 0.32), and removal of it and the other taxa under 0.32 TRC does clear up the BDC and MDS patterns, showing positive correlation/clustering between *Archaeopteryx* and *Bambiraptor* only (Appendix, Figs. 66–677).

These results agree with what was previously reported by Garner et al. (2013). They found strong evidence for discontinuity between non-avian theropods and avialans. Interestingly, they also discovered *Archaeopteryx* to be difficult to classify. In some analyses, it clustered with deinonychosaurs, but in others it clustered with avialans. At this point, we still cannot say with certainty whether *Archaeopteryx* is continuous with some avialan

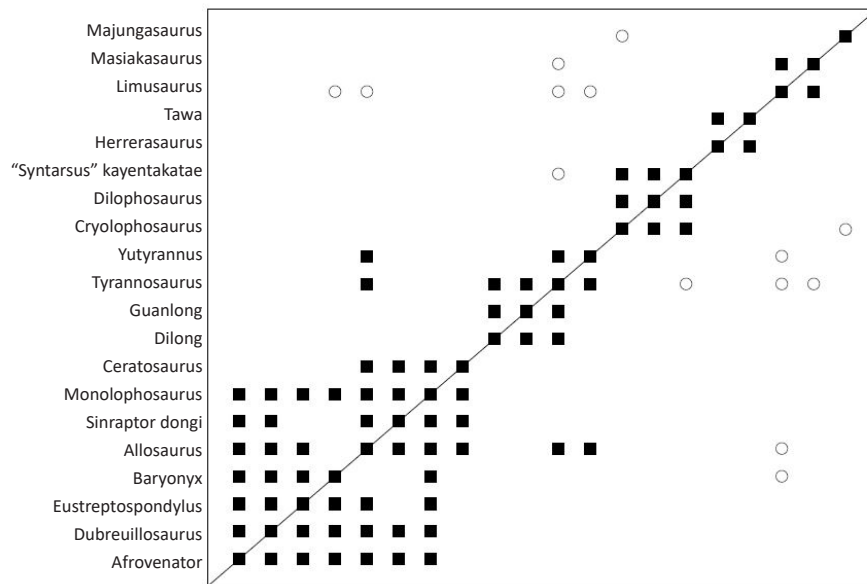


Figure 40. BDC results of the Tyrannosauroidae + non-coelurosaur theropod subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

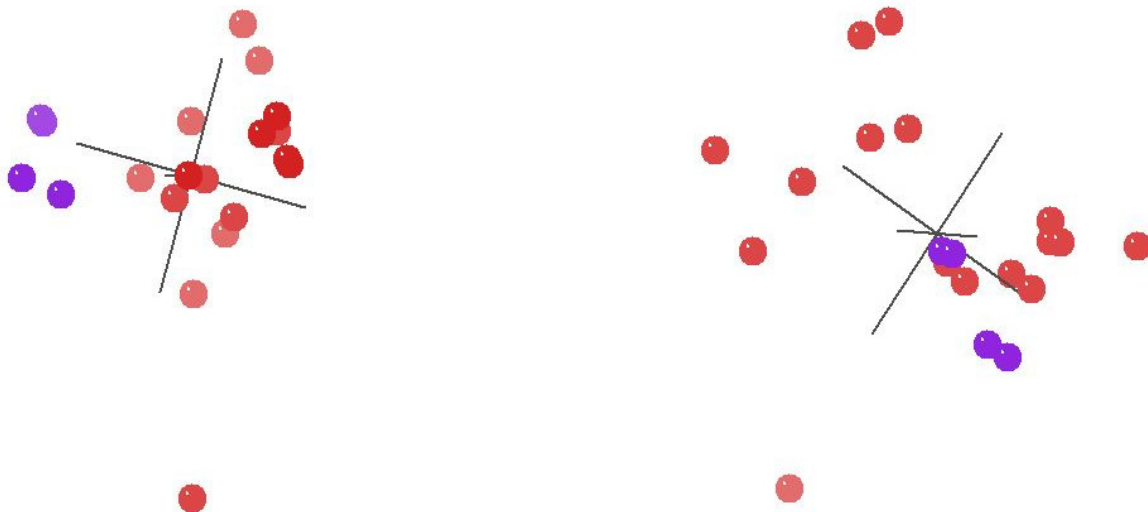


Figure 41. MDS results of the Tyrannosauroidae + non-coelurosaur theropod subset of the Lee et al. (2014) dataset in two views (left, right). Colors: red – non-coelurosaur theropod; purple – Tyrannosauroidae.

taxa or dromaeosaurids.

B. *Deinonychosauria*

Dromaeosaurids and troodontids both appear to be discontinuous from most “basal” avialans (as discussed above) and scansoriopterygids (see Figs. 58 and 59) based on a lack of positive correlation and sometimes negative correlation in BDC results and separation from these taxa in MDS. However, the relationship of dromaeosaurids to troodontids is a little more difficult to determine. In the BDC results for the paravian subsets of Brusatte et al. (2014) and Lee et al. (2014) there are clear instances of shared positive correlation between dromaeosaurids and troodontids (Figs. 20 and 36). The 3D MDS results for these paravian subset analyses all show clustering between dromaeosaurids and troodontids (Figs. 21 and 37). In the paravian subset BDC of van der Reest and Currie (2017), there are links of positive correlation between

dromaeosaurids and troodontids mainly through *Buitreraptor* and *Anchiornis* (Fig. 58), and the MDS shows them as two separate clusters with *Buitreraptor* in between (Fig. 59). The Zanno (2010) BDC, which only included dromaeosaurids, troodontids, *Archaeopteryx*, and *Confuciusornis*, showed no correlation of any kind between dromaeosaurids and troodontids (Fig. 48), and a gap in morphological space between their clusters (Fig. 49).

Thus, all of these analyses, except for Zanno (2010), show evidence of continuity between Dromaeosauridae and Troodontidae. It is worth noting that Zanno (2010) is the oldest of the datasets, and its focus is on therizinosaurs, not paravians. Additional evidence for continuity between Dromaeosauridae and Troodontidae comes in the form of the unenlagiine *Buitreraptor*. Unenlagiines are a long-snouted subfamily of dromaeosaurids exclusively known from the southern hemisphere. Interestingly, in the analysis of the paravian

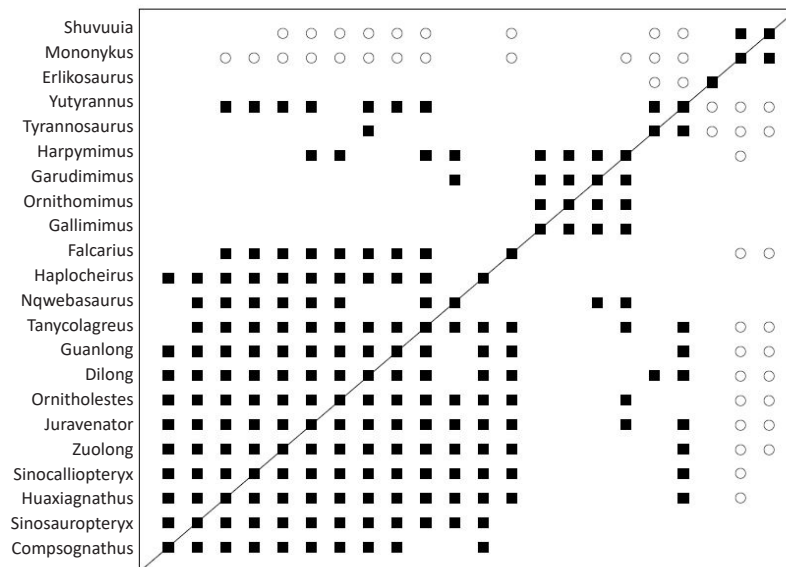


Figure 42. BDC results of the non-pennaraptoran coelurosaur subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

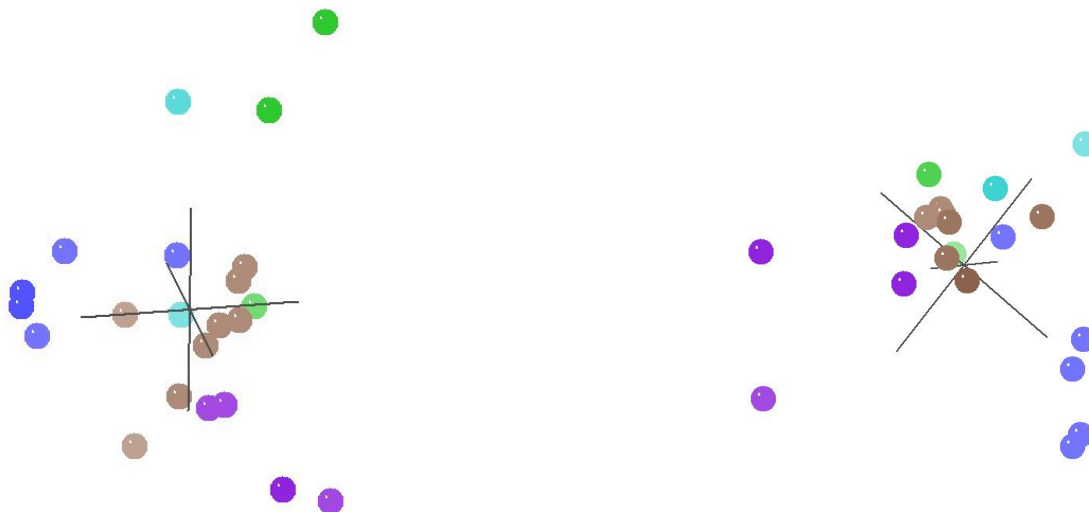


Figure 43. MDS results of the non-pennaraptoran coelurosaur subset of the Lee et al. (2014) dataset in two views (**left, right**). Colors: turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroida.

subset of van der Reest and Currie (2017), the BDC results showed *Buitreraptor* inside the troodontid block of positive correlation rather than inside the dromaeosaurid block, a result also found by Wood (2011). It may be that the inclusion of more unenlagiine taxa in the future could strengthen the evidence for continuity between these two families. Thus, we tentatively suggest that Deinonychosauria may be a holobaramin containing the two monobaramins Dromaeosauridae and Troodontidae.

C. Scansoriopterygidae

Only one analysis (van der Reest and Currie, 2017) contained scansoriopterygid taxa, and the BDC results of both the paravian subset and the oviraptorosaur subset show scansoriopterygids as not sharing positive correlation with any other taxa (Figs. 58 and 60). In fact, they are negatively correlated with some troodontids and oviraptorosaurs in these BDC plots. Additionally, the 3D MDS results for these analyses never show them clustering with any other taxa (Figs. 59 and 61). Based on these results, we suggest that

Scansoriopterygidae is a holobaramin. Our conclusion is consistent with the BDC results for the paravian subset of data in Wood (2011, Fig. 3). *Epidendrosaurus* is the only scansoriopterygid included in the analysis, and it does not share any correlation with any other taxa.

D. Oviraptorosauria

Oviraptorosaurs are very unique animals as evidenced by their bizarre, fore-shortened, beaked faces, and their uniqueness is evident in these baraminological analyses. They do not correlate positively with any non-oviraptorosaur taxa in the BDC results of any of the pennaraptoran or oviraptorosaur subset analyses (Figs. 30, 34, 50, and 60). The BDC results for the oviraptorosaur dataset (Lamanna et al. 2014) show negative correlation or no correlation separating oviraptorosaurs from the outgroup (Fig. 64). The 3D MDS results consistently show oviraptorosaurs as not clustering with non-oviraptorosaur taxa (Figs. 31, 35, 51, 61, and 65). Thus, we suggest that Oviraptorosauria is an apobaramin.

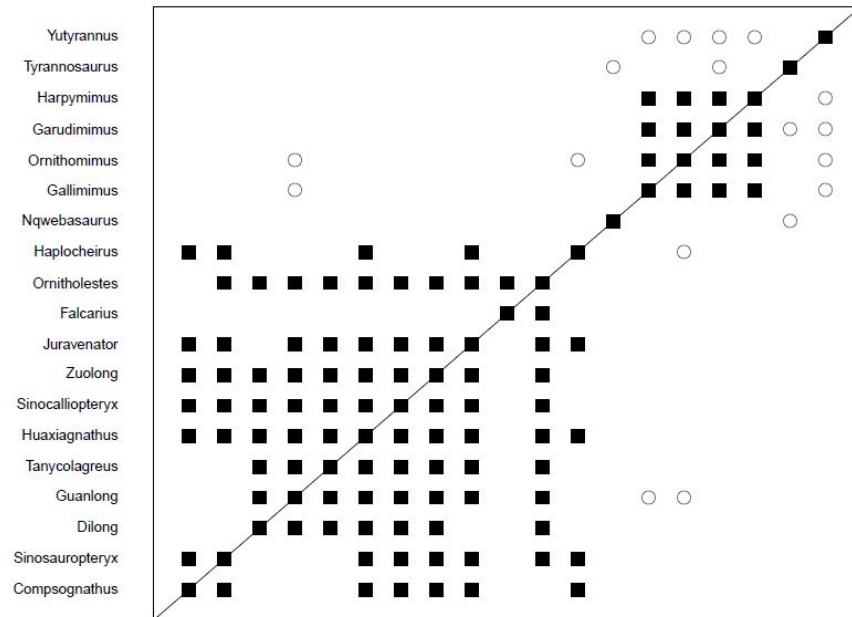


Figure 44. BDC of the *Falcarius* + non-maniraptoran coelurosaur subset of the Lee et al. (2014) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

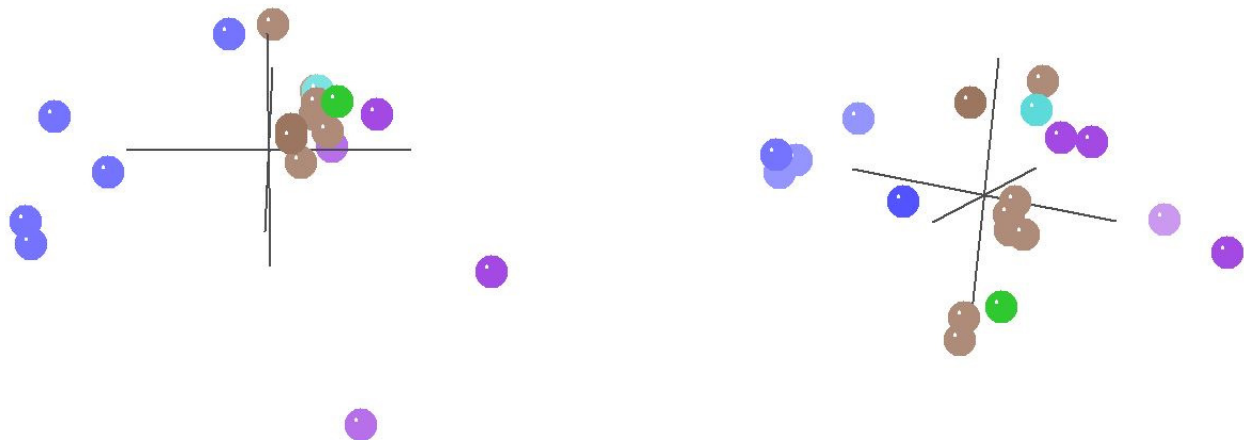


Figure 45. MDS results of the *Falcarius* + non-maniraptoran coelurosaur subset of the Lee et al. (2014) dataset in two views (**left, right**). Colors: turquoise – Therizinosauroidea; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidae.

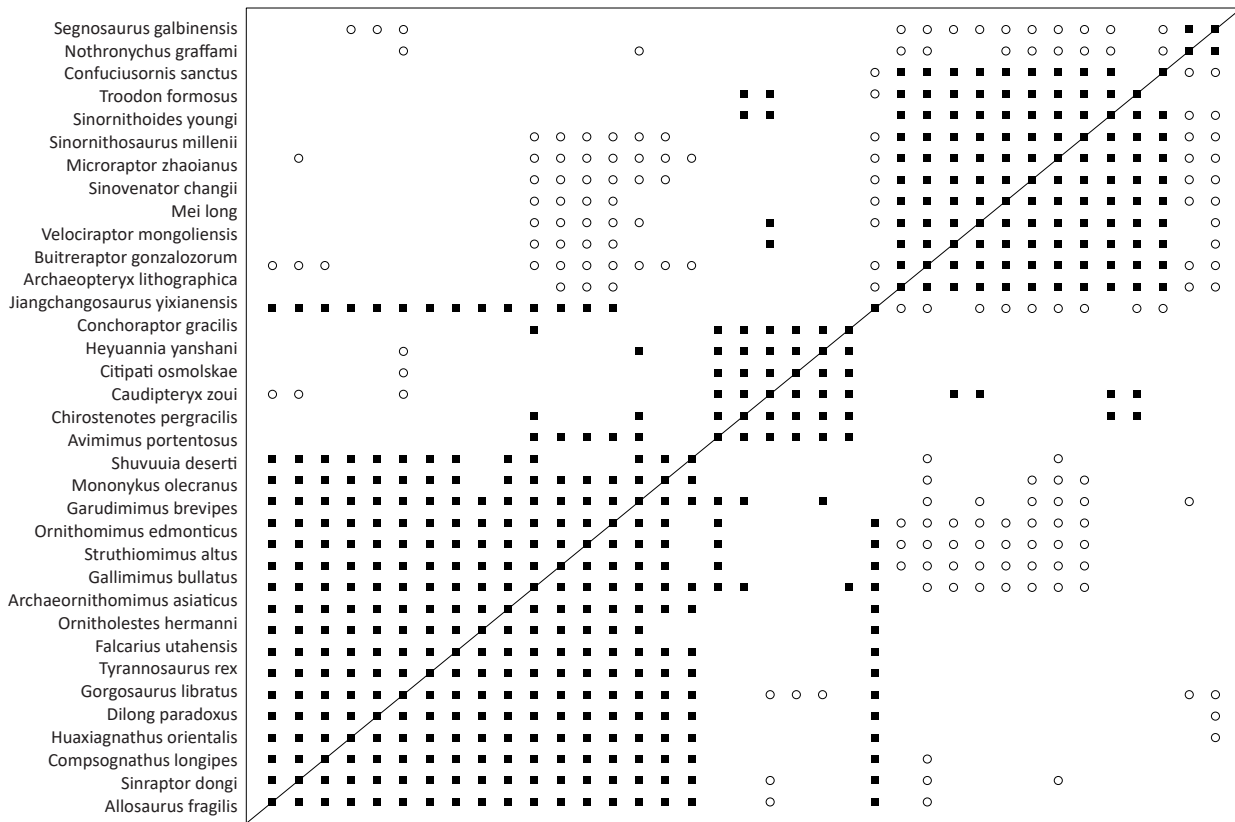


Figure 46. BDC results of the Zanno (2010) analysis. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

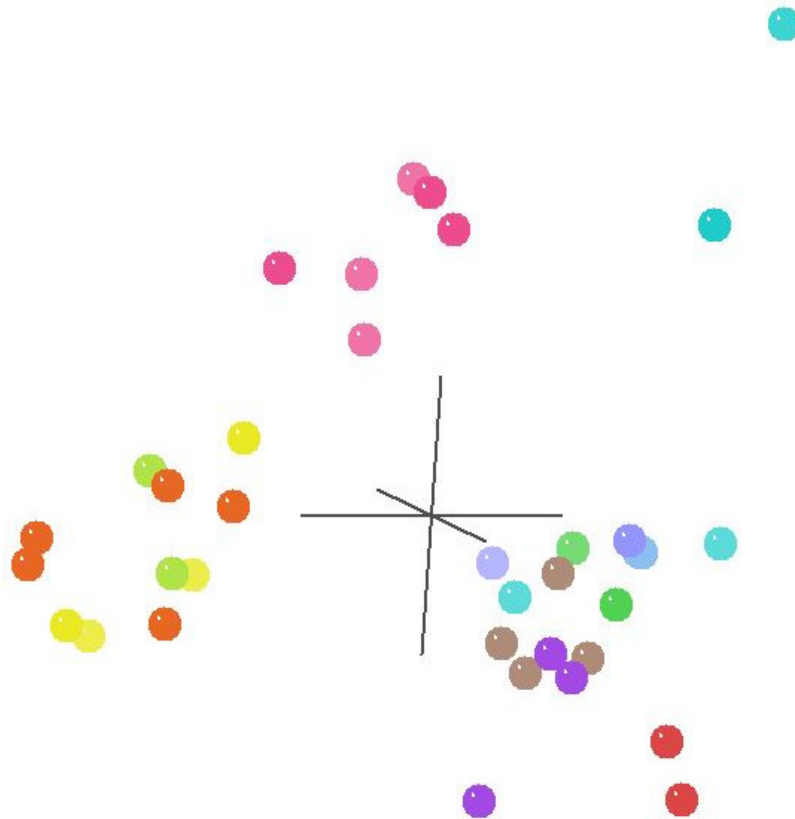


Figure 47. MDS results of the Zanno (2010) analysis. Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria; turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidea.

Oviraptorids consistently show positive correlation with each other and cluster together. However, other oviraptorosaur taxa such as caenagnathids (e.g., *Chirostenotes* and *Anzu*), caudipterids, and “basal” oviraptorosaurs (e.g., *Avimimus*, *Incisivosaurus*, and *Protarchaeopteryx*) often do not correlate positively with oviraptorids or cluster together with them in MDS. *Caudipteryx*, *Chirostenotes*, *Microvenator*, and *Avimimus* positively correlate with oviraptorids in the oviraptorosaur subset analysis of Zanno (2010) (Fig. 50), and they are closely clustered with the oviraptorids in the 3D MDS results (Fig. 51). *Incisivosaurus*, however, does not cluster or positively correlate with the other oviraptorosaurs. *Incisivosaurus* proved to be a difficult taxon in several of the analyses. As in the Zanno (2010) oviraptorosaur subset, *Avimimus* and *Chirostenotes* positively correlate with at least one oviraptorid each in the BDC results of the van der Reest and Currie (2017) oviraptorosaur subset (Fig. 60). However, *Caudipteryx* does not show evidence of continuity in this analysis, and neither does *Protarchaeopteryx*. The Lamanna et al. (2014) analysis was the only one that specifically focused on oviraptorosaurs. Its BDC results do not show positive correlation between any oviraptorid and non-oviraptorid oviraptorosaurs at a

0.5 TRC. However, at a 0.3 TRC there is shared positive correlation between *Gigantoraptor* and *Anzu* and *Conchoraptor* (Appendix, Fig. 74). This hints at the possibility that many of the non-oviraptorid oviraptorosaurs probably are continuous with oviraptorids, but that the taxa connecting them are poorly known. At this point, we can say Oviraptoridae is a monobaramin and Oviraptorosauria is an apobaramin. However, it is difficult to know exactly how many holobaramins Oviraptorosauria contains. It could be one holobaramin, or several (possibly Oviraptoridae, Caudipteridae, and Caenagnathidae are separate holobaramins).

E. Therizinosauria

Therizinosaurids are peculiar animals with stocky bodies, long necks, scythe-like hand claws, and superficially ornithischian-like skulls that are unfortunately known from rather fragmentary remains. In fact, the only really well known therizinosaurids are the basal forms *Falcarius* and *Jianchangosaurus*, which are both outside of Therizinosauridae. *Beipiaosaurus* and *Alxasaurus* are known from partial skeletons, but the only members of Therizinosauridae known from somewhat decent remains are *Nothronychus*, *Segnosaurus*, and *Erlisaurus*. As such, including therizinosaurids

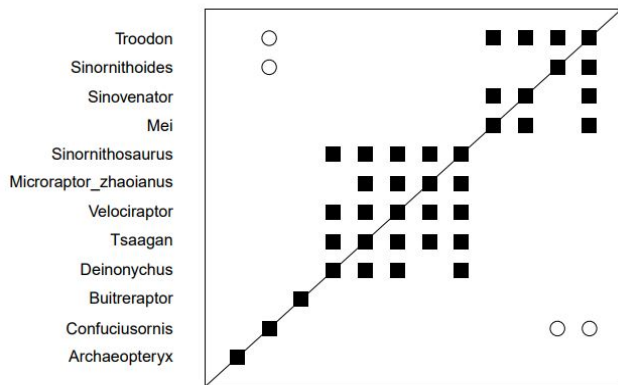


Figure 48. BDC results of the Paraves subset of the Zanno (2010) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

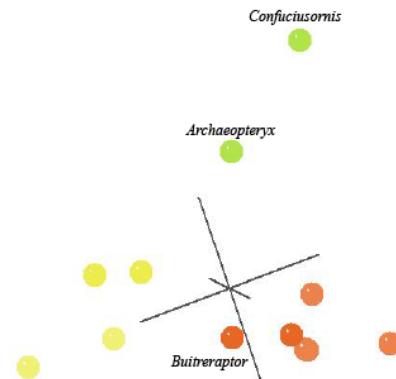


Figure 49. MDS results of the Paraves subset of the Zanno (2010) dataset. Colors: orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae.

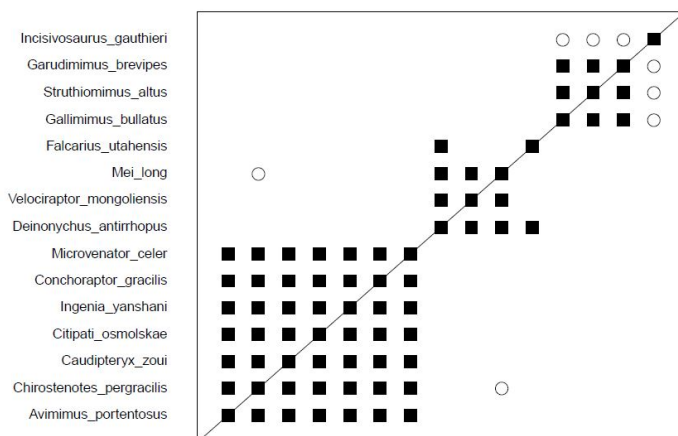


Figure 50. BDC results of the Oviraptorosauria subset of the Zanno (2010) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

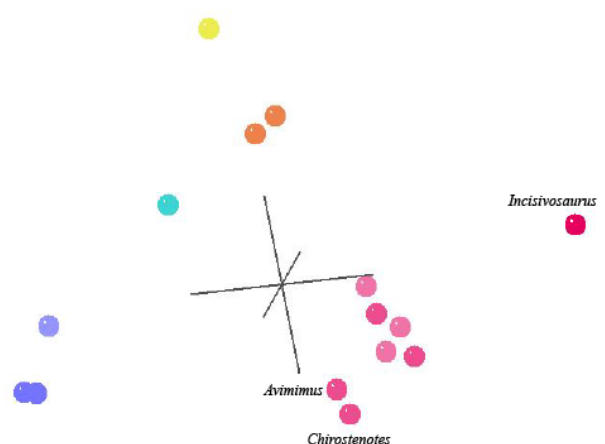


Figure 51. MDS results of the Oviraptorosauria subset of the Zanno (2010) analysis. Colors: orange – Dromaeosauridae; yellow – Troodontidae; pink – Oviraptorosauria; turquoise – Therizinosauria; blue – Ornithomimosauria.

in the baraminological analyses has been challenging. Typically, only *Falcarius* and one or two therizinosaurs are included in the analyses. These analyses always showed the therizinosaurid taxon or taxa (for a Brusatte et al. (2014) subset) as sharing negative or no correlation with the other taxa in BDC plots (e.g., Figs. 30, 42, and 62). No analysis ever showed positive correlation between *Falcarius* and other therizinosaurs. Even in the analysis that included the most therizinosaurs, the therizinosaur subset of Zanno (2010), the BDC revealed positive correlation between *Falcarius* and the outgroup taxa rather than with any therizinosaurs (Fig. 52).

We will focus our discussion on the therizinosaur subset analysis of Zanno (2010), since it was the only analysis to contain more than three therizinosaur taxa. The BDC results (Fig. 52) show positive correlation between the therizinosaurs and *Alxasaurus*, which we interpret as evidence for continuity. *Beipiaosaurus* is positively

correlated with only *Alxasaurus* and *Jianchangosaurus*, which is correlated with nothing else. Thus, we tentatively interpret the BDC results to mean that all of these therizinosaurs are continuous with each other and discontinuous from other theropods. Additionally, the 3D MDS results of the same Zanno (2010) subset reveal an intriguing pattern. The therizinosaurs make a line in morphological space, with *Jianchangosaurus* on one end and *Segnosaurus* on the other (Fig. 53). It is difficult to tell from the figure, but *Erlikosaurus* is a little removed from the trajectory, but is closest to the *Segnosaurus* end. It would appear that the therizinosaur taxa form a biological trajectory, much like Cenozoic equids (Cavanaugh et al. 2003) and Mesozoic tyrannosauroids (Aaron, 2014b). These taxa are lined up, in general, according to their evolutionary trajectory, with *Jianchangosaurus* as a basal therizinosaurian, followed by the non-therizinosaurid therizinosaurids *Beipiaosaurus* and *Alxasaurus*, which are in turn followed by the derived therizinosaurs.

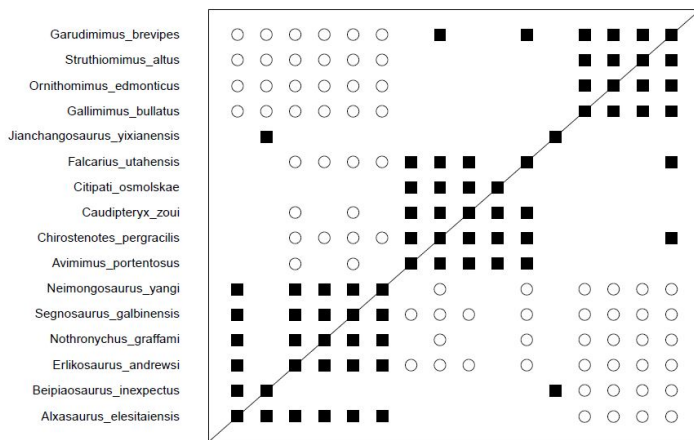


Figure 52. BDC results of the Therizinosauria subset of the Zanno (2010) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

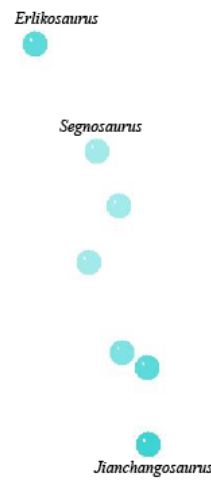


Figure 53. MDS results of the Therizinosauria subset of the Zanno (2010) dataset. Colors: pink – Oviraptorosauria; turquoise – Therizinosauria; blue – Ornithomimosauria.

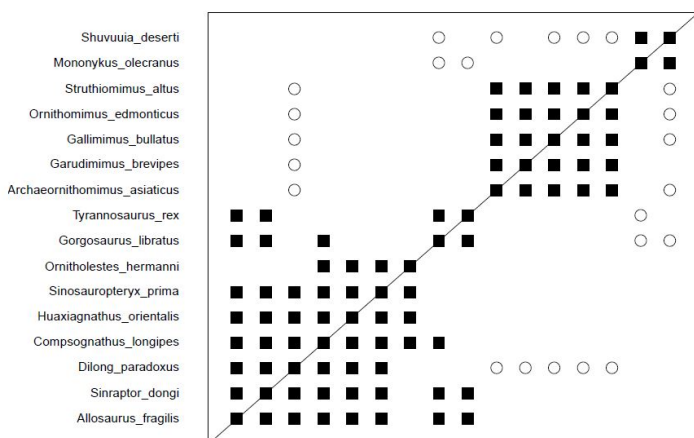


Figure 54. BDC results of the Alvarezsauroidae + non-maniraptoran coelurosaur subset of the Zanno (2010) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

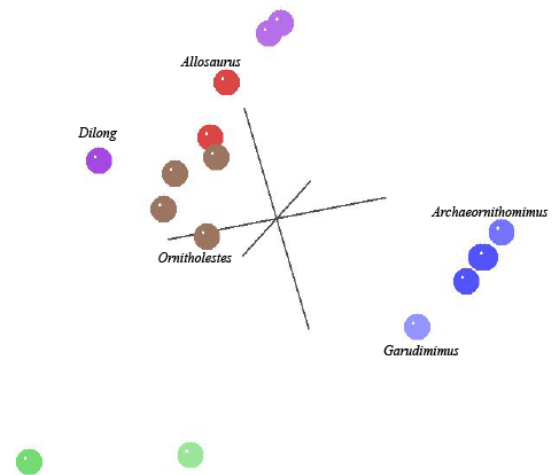


Figure 55. MDS results of the Alvarezsauroidae + non-maniraptoran coelurosaur subset of the Zanno (2010) dataset. Colors: green – Alvarezsauroidae; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidae.

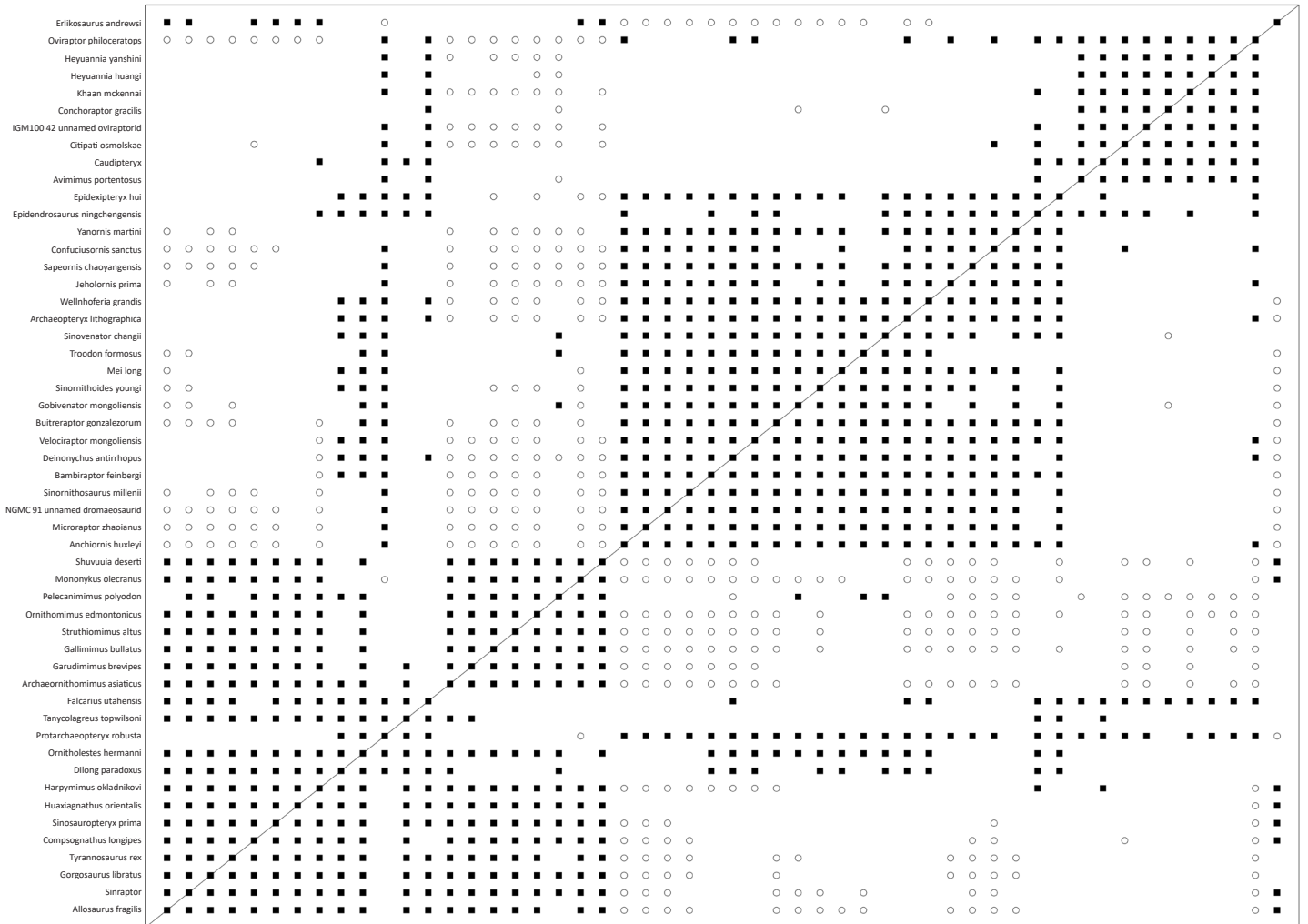


Figure 56. BDC results of the van der Reest and Currie (2017) analysis. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

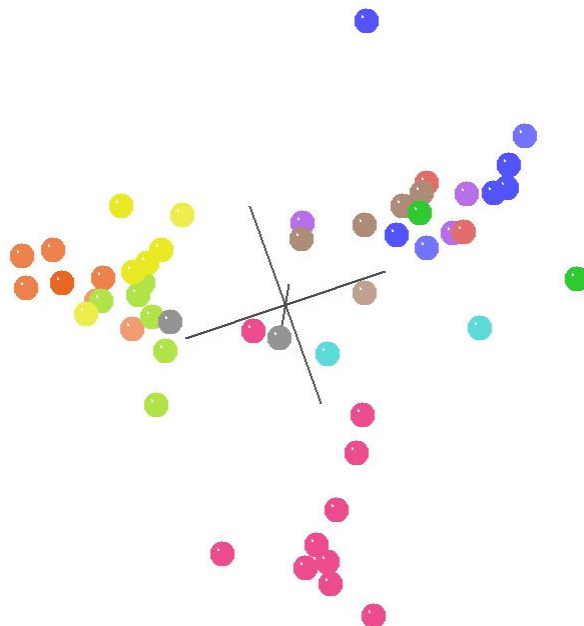


Figure 57. MDS results of the van der Reest and Currie (2017) analysis. Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria; turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidae; gray – Scansoriopterygidae.

However, these taxa are also lined up chronostratigraphically, with the oldest taxa on the most basal end of the trajectory, and the youngest taxa on the most derived end. None of the taxa are out of order chronostratigraphically. However, it is worth noting that *Jianchangosaurus* and *Beipiaosaurus* are from the same general stratigraphic horizon (the Yixian Formation of Jinzhou, Lianoning, China).

Interestingly, Fig. 53 does not show *Falcarius* on the therizinosaur trajectory. This agrees with the BDC results from that same analysis

(Fig. 52). At this point, we tentatively suggest that Therizinosauria without *Falcarius* is a holobaramin. However, based on the similarities in anatomy between *Falcarius* and therizinosaurs, especially *Jianchangosaurus*, we would not be surprised if it turns out that *Falcarius* is within the therizinosaur holobaramin.

F. *Alvarezsauroidea*

Alvarezsaurids are bizarre dinosaurs, possessing one finger considerably more robust than the others. In some alvarezsaurids, there is only one finger on each hand (e.g., *Mononykus*). The

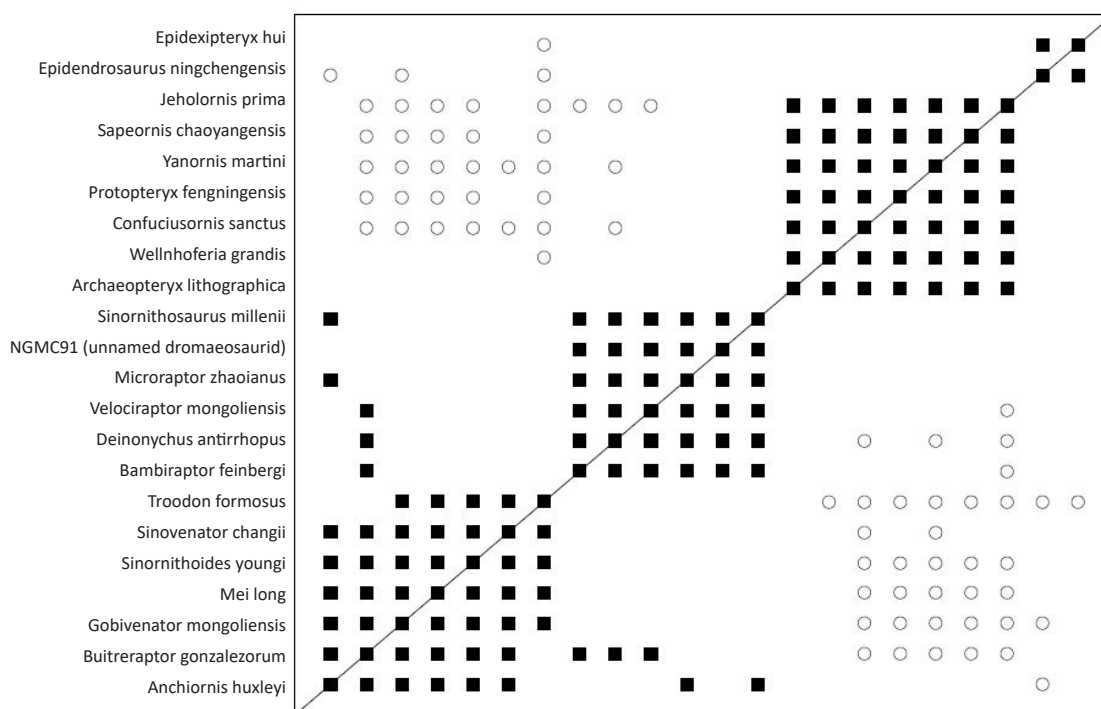


Figure 58. BDC results of the Paraves subset of the van der Reest and Currie (2017) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

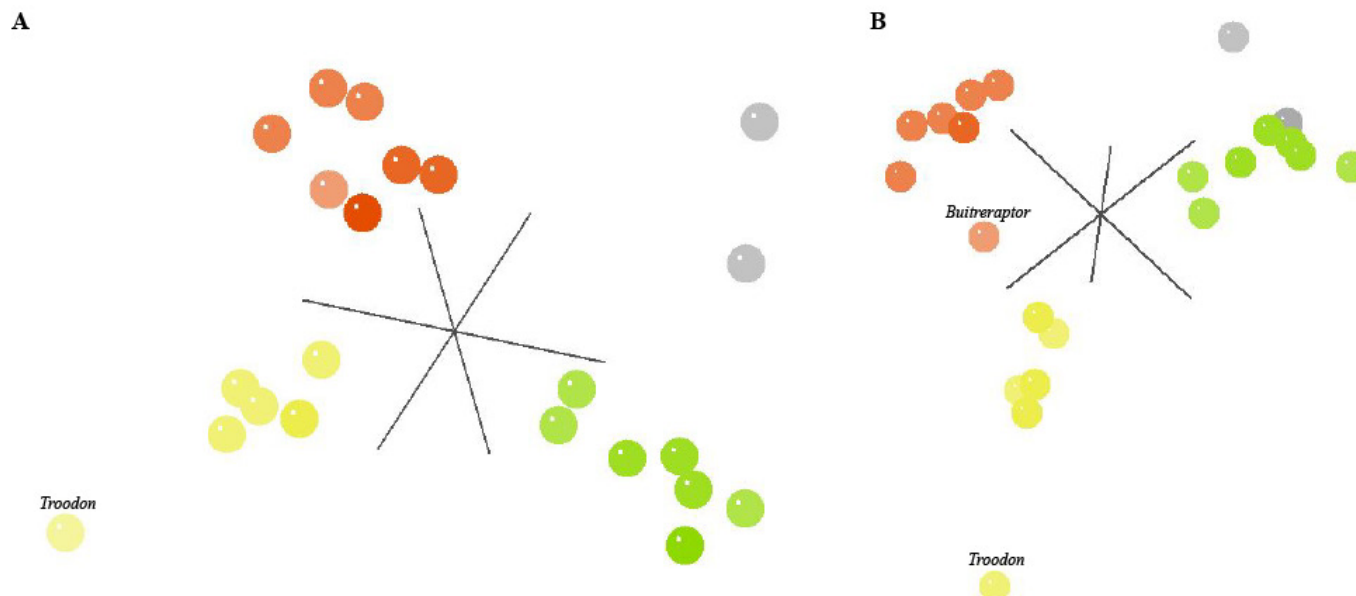


Figure 59. MDS results of the Paraves subset of the van der Reest and Currie (2017) dataset in two views (A and B). Colors: orange – Dromaeosauridae; yellow – Troodontidae; light green – Alvarezsauridae; gray – Scansoriopterygidae.

genus *Haplocheirus* is thought to be an alvarezsauroid outside Alvarezsauridae. Like the alvarezsaurids, its first digit on each hand is more robust than the other digits, but unlike alvarezsaurids the other fingers are long and functional. Other than *Haplocheirus*, *Mononykus*, and *Shuvuuia*, most alvarezsauroids are very poorly known. In fact, only one analysis was able to retain more alvarezsauroids than these three (*Patagonykus* is in the Brusatte et al. (2014) alvarezsauroid + ornithomimosaur + “basal” coelurosaur subset analysis). Alvarezsaurids are incredibly distinct from the other theropods in the most exclusive subset analyses that contain them. The BDC plots from these analyses show negative correlation or no correlation between alvarezsaurids and the rest of the taxa (Figs. 26, 42, 54, and 62). Additionally, they do not cluster together

with other taxa in the 3D MDS plots from these analyses (Figs. 27, 43, 55, and 63). This suggests Alvarezsauridae is surrounded by discontinuity.

Haplocheirus never shows any links to the alvarezsaurid taxa in any analysis. This could be because it is not in the same holobaramin as alvarezsaurids. Another possibility is that the taxa that would link *Haplocheirus* to alvarezsaurids are poorly known or unknown. This seems likely given the fact that most analyses only contained three alvarezsauroids, the most “basal” form and two of the most “derived” forms. At this point, we tentatively suggest that Alvarezsauridae is a holobaramin, but we suspect that future analyses may reveal that the holobaramin is actually at the

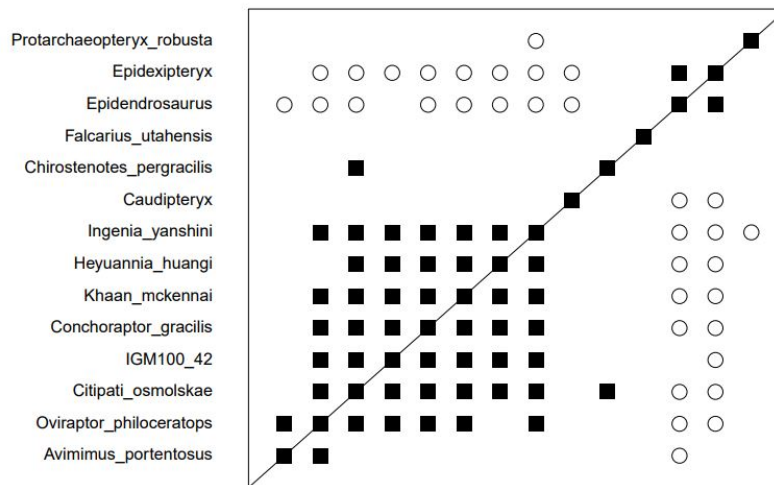


Figure 60. BDC results of the Oviraptorosauria subset of the van der Reest and Currie (2017) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

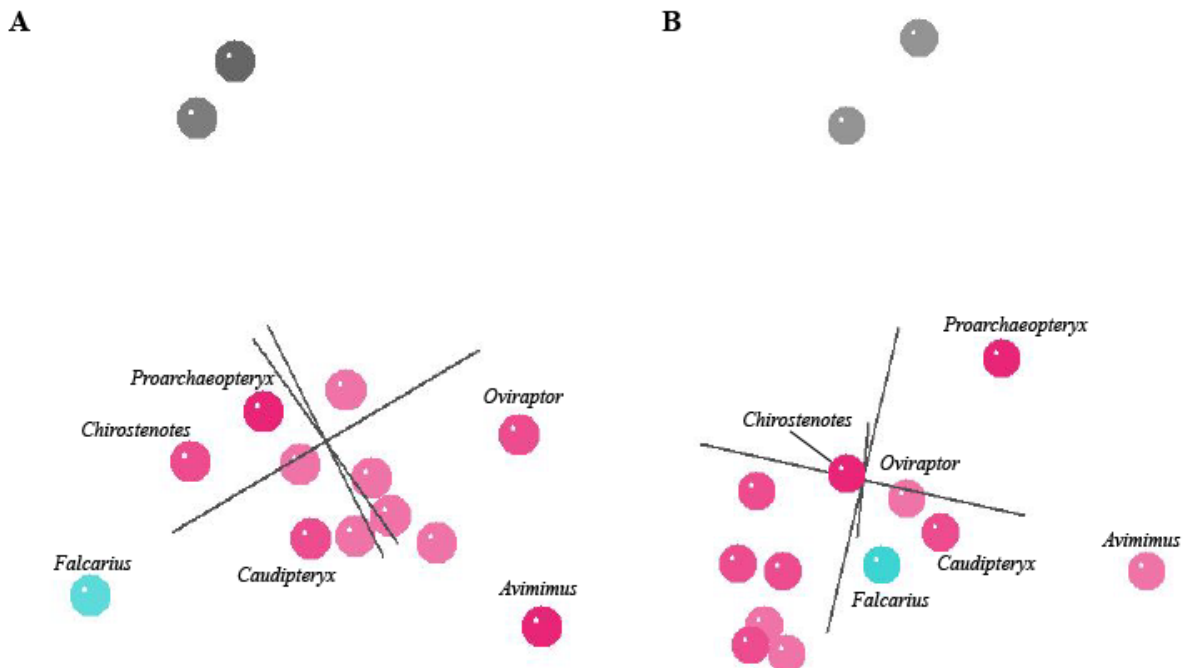


Figure 61. MDS results of the Oviraptorosauria subset of the van der Reest and Currie (2017) dataset in two views (A and B). Colors: pink – Oviraptorosauria; turquoise – Therizinosauria; gray – Scansoriopterygidae.

level of Alvarezsauroidea, including *Haplocheirus*.

G. Ornithomimosauria

Ornithomimosaurians are distinct, readily recognizable dinosaurs. They are often referred to as “ostrich mimics” because they look similar to ostriches in their toothless skulls set on long necks

and their long legs built for running. Most ornithomimosaurians do not vary much from this body plan. Some “basal” forms, such as *Pelecanimimus*, possess many tiny teeth, but the strangest variation of ornithomimosaur is the duck-billed, hump-backed, giant *Deinocheirus*. Sadly, none of the analyses included the new material of *Deinocheirus*, which means that we were unable to

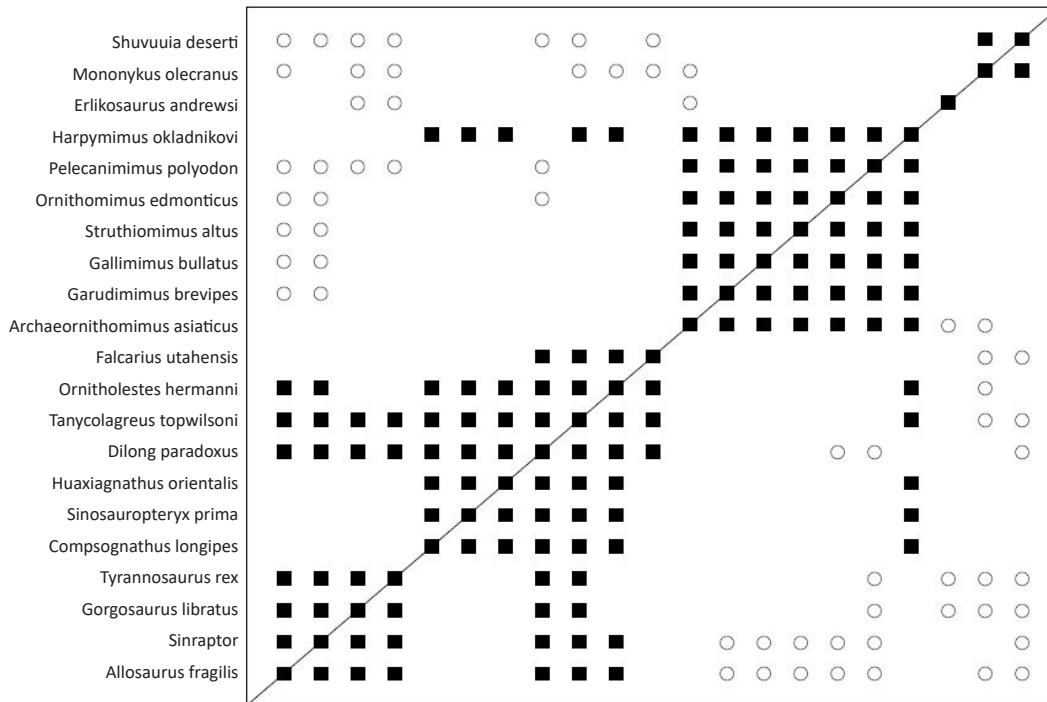


Figure 62. BDC results of the non-pennaraptoran theropod subset of the van der Reest and Currie (2017) dataset. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

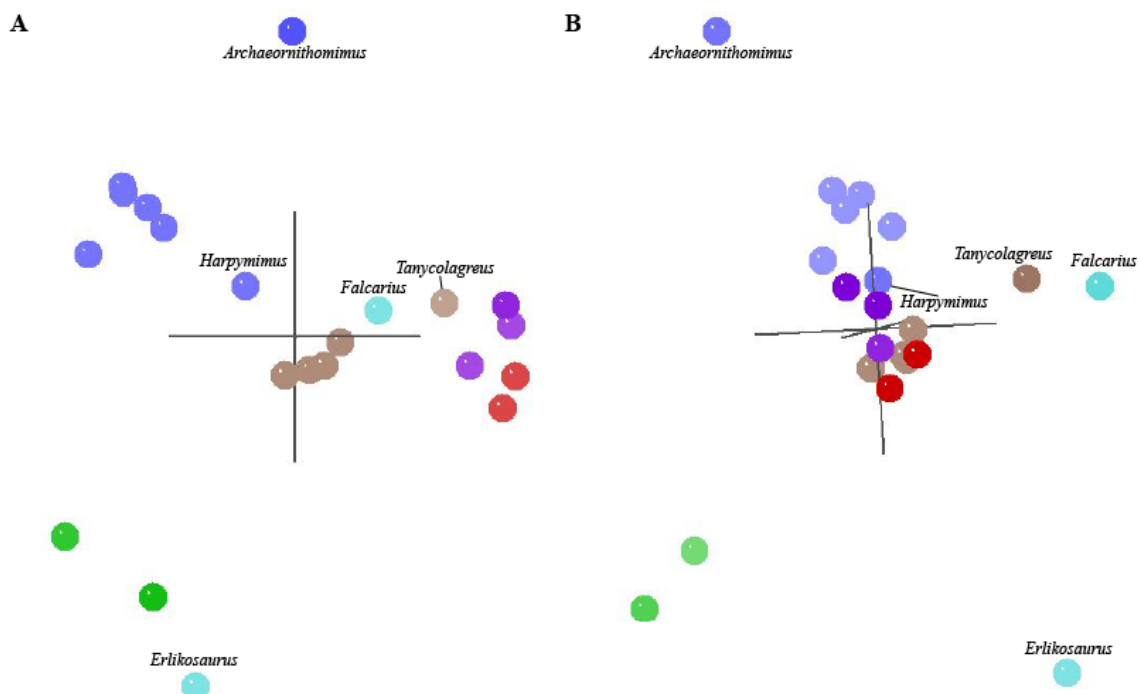


Figure 63. MDS results of the non-pennaraptoran theropod subset of the van der Reest and Currie (2017) dataset in two views (A and B). Colors: red – non-coelurosaur theropod; turquoise – Therizinosauria; green – Alvarezsauroidea; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroida.

evaluate its baraminic relationship to the other ornithomimosaurs.

Ornithomimosaurs consistently clustered together in 3D MDS plots (Figs. 29, 43, 55, and 63) and share positive correlation in BDC plots (Figs. 28, 42, 54, and 62). These clusters/blocks of positive correlation consistently contained ornithomimids, as well as “basal” ornithomimosaurs (e.g., *Pelecanimimus*, *Harpymimus*) and deinocheirids (e.g., *Garudimimus*), although some MDS plots show *Archaeornithomimus* or *Pelecanimimus* in unusual positions. The BDC plot for the van der Reest and Currie (2017) non-pennaraptoran subset does show *Harpymimus* positively correlated with some coelurosaurs, but that is because the alvarezsaurids and *Erlikosaurus* are present in the analysis. Removal of these very disparate taxa results in ornithomimosaurs all positively correlated with one another and negatively correlated or not correlated at all with the other theropod taxa (Appendix, Fig. 72). Although some of these analyses only contained a handful of ornithomimosaur taxa, the Brusatte et al. (2014) analysis contained 10 ornithomimosaur taxa. Because ornithomimosaurs appear to be continuous with each other and discontinuous from other theropods, we interpret Ornithomimosauria to be a holobaramin.

Nqwebasaurus has recently been considered the most basal ornithomimosaur (Choiniere et al. 2012). *Nqwebasaurus* had a low taxic relevance probably because the characters were not updated by the dataset authors to account for the newly described material. Although *Nqwebasaurus* never clusters with the ornithomimosaurs in the 3D MDS results we obtained, it is always closer to the ornithomimosaur cluster than the other “basal” coelurosaurs. It is possible that future analyses may find continuity between *Nqwebasaurus* and ornithomimosaurs.

H. Tyrannosauroidae

Tyrannosauroid baraminology has already been discussed at length by Aaron (2014b), and apart from Brusatte et al. (2014), these analyses contain very few tyrannosauroid taxa, so they add very little information. The results obtained from the tyrannosauroid + “basal” coelurosaur and “basal” tyrannosauroid + “basal” coelurosaur subset analyses of Brusatte et al. (2014) agree very well with the conclusions of Aaron (2014b). Tyrannosaurids are certainly a monobaramin based on shared positive correlation

and obvious clustering in MDS. *Xiongguanlong* and *Eotyrannus* are positively correlated with one another, and the “basal” tyrannosauroid + “basal” coelurosaur subset BDC (Fig. 24) shows positive correlation with *Appalachiosaurus*, which was correlated positively with the tyrannosaurid block in the tyrannosauroid + “basal” coelurosaur BDC (Fig. 22). Additionally, the “basal” tyrannosauroid + “basal” coelurosaur BDC and MDS results show evidence for discontinuity between *Eotyrannus* + *Xiongguanlong* + *Appalachiosaurus* and “basal” Coelurosauria + *Dilong* + *Guanlong*. Interestingly, the MDS results for the tyrannosauroid + “basal” coelurosaur subset analysis (Fig. 23) show a tyrannosauroid trajectory, as was noted by Aaron (2014b). This trajectory, however, looks like it starts with *Dilong* and *Guanlong*, which was not noted in the analyses conducted by Aaron (2014b). The MDS results for the “basal” tyrannosauroid + “basal” coelurosaur subset (Fig. 25) do not seem to show such a strong trajectory.

As with Aaron (2014b), we tentatively conclude that Tyrannosauridae + *Appalachiosaurus* + *Xiongguanlong* + *Eotyrannus* is a holobaramin. Also in agreement with Aaron (2014b), we would not be surprised if *Dilong* or *Guanlong* were to show evidence of continuity with this group in later analyses, but we currently do not consider them a part of this holobaramin. Unfortunately, Brusatte et al. (2014) did not include *Yutyrannus* in their dataset. *Yutyrannus* was included in the Lee et al. (2014) dataset, but since they only included three tyrannosauroids (*Tyrannosaurus*, *Yutyrannus*, and *Dilong*), it is difficult to draw any conclusions as to its baraminic status. Without *Dilong* or *Yutyrannus* in the “tyrannosauroid holobaramin”, there are no feathered members known from this group. We suspect that *Yutyrannus* will turn out to be a member of this group, but only future analyses will tell.

I. “Basal” Coelurosauria

Unfortunately, many of these analyses treated “basal” coelurosaurs such as *Ornitholestes*, *Tanycolagreus*, and compsognathids essentially as outgroup taxa. As a result, they all clustered together and mainly shared positive correlation, which is probably masking the true diversity in this group. These taxa probably clustered together since they shared the commonality of lacking the synapomorphies of other more “derived” coelurosaur groups. This also may explain why taxa like *Haplocheirus*, *Nqwebasaurus*, and

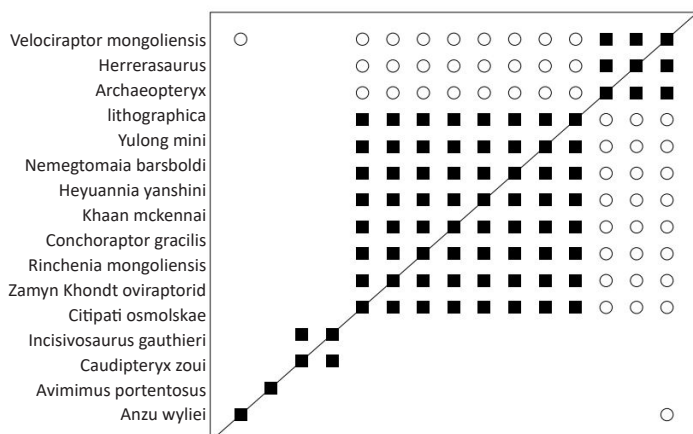


Figure 64. BDC results of the Lamanna et al. (2014) analysis run at a 0.5 TRC. Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

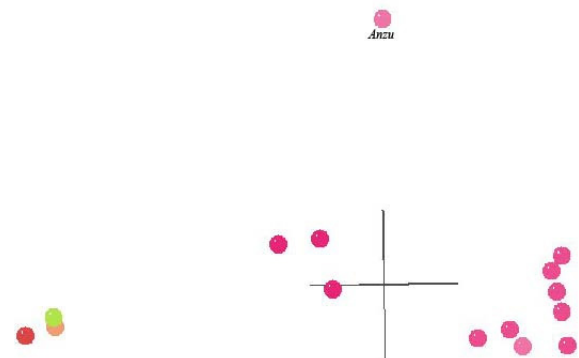


Figure 65. MDS results of the Lamanna et al. (2014) analysis run at 0.5 TRC. Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; light green – Avialae; pink – Oviraptorosauria.

Falcarius commonly clustered with these taxa. They were united by their many “0s” in the datasets.

We refrain from assigning any kind of baraminic status to these animals as of now. They appear to be discontinuous from the other groups that have been discussed with the possible exception of some of the “basal” members of those groups (e.g., *Falcarius* and *Haplocheirus*). Most likely, the “basal” coelurosaur group is artificial and probably contains more than one holobaramin

J. Summary of the Baraminology of the Feathered Dinosaurs

Through our baraminological work on coelurosaurs, we arrived at the following holobaramins: 1) Deinonychosauria (may be more than one), 2) Scansoriopterygidae, 3) Oviraptorosauria (probably more than one), 4) Therizinosauria (minus *Falcarius*), 5) Alvarezsauridae, 6) Ornithomimosauria (minus *Nqwebasaurus*), and 7) Tyrannosauridae + *Appalachiosaurus* + *Xiongguanlong* + *Eotyrannus*. Additionally, there must be at least one more holobaramin of “basal” coelurosaur. This means that, at minimum, there are probably eight different created kinds of feathered dinosaurs. None of these groups show conclusive evidence for continuity with Avialae, except for the taxon *Archaeopteryx*, which seems to be difficult to place. We suspect that *Archaeopteryx* will eventually be found to be a part of the deinonychosaur holobaramin, but we will wait on future analyses for resolution. As predicted by creationists (e.g., Clark 2007), there appear to be multiple baramins of feathered dinosaurs.

As a caution, Senter did demonstrate that morphological gaps in the fossil record tend to be filled in over time, so we recognize that creationist arguments from discontinuity are not yet conclusive. Nevertheless, based on the results of this study and Garner et al. (2013), we conclude that discontinuity exists not only between, but also within modern birds, Mesozoic fossil birds, and dinosaurs.

2. Taxonomy Discussion

Our results dovetail with the three previous creationist analyses of theropod dinosaurs and birds, giving us confidence that the creationist model of created kinds is compatible with fossil data. However, they raise a different issue for creationists. While we found that feathered dinosaurs could be broken into multiple created kinds, and others have found that birds can be broken into multiple created kinds, we could not find a way to separate theropod dinosaurs and birds overall into two groups based on their anatomy (cf. Garner et al. 2013). Traditionally, creationists have considered dinosaurs and birds to be two discrete groups, easy to separate and identify (e.g., Silvestru 2007). To most people, dinosaurs and birds appear to be vastly different animals. However, such a distinction can only be maintained by “cherry picking” non-birdlike dinosaurs for comparison. For instance, if sparrows, eagles, and flamingoes are compared with *Triceratops*, *Diplodocus*, and *Stegosaurus*, it is obvious that the birds belong to a different group from the dinosaurs. A much different picture appears if we compare birds to the theropod dinosaurs, and especially to the smaller coelurosaurs. The similarities are progressive from coelurosaurs to living birds, creating an anatomical spectrum of features. *Dilong* is not very similar to *Corvus* (living crows). But *Dilong* is similar to *Compsognathus*, *Compsognathus* to *Deinonychus*, *Deinonychus* to *Archaeopteryx*, *Archaeopteryx* to *Cathayornis* (a clawed, toothed

enantiornithine bird with a pygostyle), *Cathayornis* to *Ichthyornis* (a toothed ornithurine bird without claws), and *Ichthyornis* to *Corvus*. These similarities are not merely subjective; when the skeletal features are mathematically quantified, and patterns of similarity analyzed as in our study, no enormous gulf can be found between coelurosaurs and birds. None of these analyses included feathers, which means these patterns are present even aside from the discovery of feathers on small dinosaurs, which only heightens the degree of similarity.

Adding to the complexity of the situation is the difficulty of categorizing specific fossil species within existing, traditional, creationist, taxonomic categories. As discussed above, *Archaeopteryx* is so similar to both dromaeosaurids and some avialans that multiple creationist studies cannot determine whether it is continuous with traditional dinosaurs or birds. Indeed, creationists have disagreed over what *Archaeopteryx* is since its discovery. Within two years of its discovery, two paleontologists opposed to Darwinism had published papers on *Archaeopteryx*, one claiming that it was a reptile with skin structures that merely looked like feathers (Wagner 1862), and the other that it was unequivocally a bird, albeit an unusual one (Owen 1863). In the 1980s, multiple non-Darwinian scientists claimed that *Archaeopteryx* was a forgery, a combination of a real dinosaur fossil and fake feather imprints (e.g., Hoyle and Wickramasinghe 1986). Although the idea was discredited a couple years after it emerged, some creationists continue to repeat this claim (Brown 2008; Taylor 1990). Other creationists have followed Owen by claiming that *Archaeopteryx* is just an unusual bird (Gish 1973; Gish 1986), with some justifying this claim by quoting Feduccia as reported by Morell (1993) (Comfort 2008, p. 129; Sarfati 1999, p. 58). However, the quote is taken out of context because Feduccia has clarified his opinion by stating that *Archaeopteryx* is, “...the most superb example of a specimen perfectly intermediate between two higher groups of living organisms...” (Feduccia 1999, pp. 1, 29). Historically, creationists have been unable to reach agreement over what *Archaeopteryx* is, so its taxonomic identity cannot be obvious.

Research by creationist paleontologists, whether using baraminological analyses, or simply looking at key morphological features, reveal patterns that are similar to those found by evolutionary methods. Although we disagree radically about its cause, both evolutionist and creationist paleontologists see a similar pattern: between what were traditionally called dinosaurs and living birds is a zone of fossil species with many traditional characteristics of both groups, so blurred and varied that it is impossible to be dogmatic about whether to call some of them birds or not. To an evolutionist, the growing lack of a significant anatomical gulf between theropod dinosaurs and birds is not surprising, since it was predicted by the hypothesis that birds evolved from theropods. To a creationist, the lack of a significant anatomical gulf may not have been predicted, but it need not be troubling. Our baraminological analyses reveal the presence of discontinuities between groups of feathered animals assumed to belong to separate created kinds, so it does not concede or imply evolution. It does imply that these groups cannot be clearly divided into either dinosaurs or birds, however. In fact, one of these groups may contain both a species

traditionally called a bird (*Archaeopteryx*), and various species traditionally called dinosaurs (*Deinonychus*, *Velociraptor*, etc.), all of which are more similar to each other than to living birds or other dinosaurs. The biological reality—a spectrum of animals with varying features that would have been considered reptilian or avian a century ago—prevents both evolutionists and creationists from drawing clear semantic dividing lines between birds and dinosaurs. This new reality of paleontology raises the question whether existing taxonomic categories and terminology are adequate to describe the diversity of life. Since we cannot clearly distinguish between theropod dinosaurs and birds, what do the terms *dinosaur* and *bird* even mean? How do we define different groups if they lack a clear boundary? How should creationists approach classification and taxonomy? To really understand what the absence of large-scale discontinuities means, it helps to take both a wide-scale and a narrow-scale look at nature.

When viewed from a wide-scale, “zoomed out” perspective, the animals we traditionally call birds and the animals we traditionally call theropod dinosaurs blur together, as evidenced by the initial BDC and MDS plots for many of our analyses before we broke them into subsets (e.g., Figs. 17, 18, 19, 32, and 33). At a figuratively high level—too far away to see the “clusters” that represent the original created kinds—birds and theropod dinosaurs (especially coelurosaurs) are overlapping, continuous, and anatomically grade into one another. Any line drawn at this level is necessarily arbitrary, and a real, morphological feature that divides birds and dinosaurs is not apparent. Indeed, when viewing all of life from a broad perspective, we can understand why evolutionists believe that birds evolved from dinosaurs. If Darwinian evolution were true, then it would be reasonable to conclude that birds evolved from dinosaurs. From a creationist perspective, this pattern does not change; merely the interpretation. The groups we call *birds* and *dinosaurs* are not evolutionarily related; rather, *birds* are a cluster of similar created kinds that nests in another, larger cluster of similar created kinds called *dinosaurs*, much like the cluster of similar created kinds we call *bats* nests in the larger cluster of similar created kinds we call *mammals*. Our historical expectation as creationists—that the animals we call birds are a discrete group wholly separate anatomically from any member of the group we call reptiles—is not corroborated by the fossil record.

Only when we use baraminological methods to “zoom in” for a narrow-scale, closer view of life—examining fewer genera or families without extensive outgroups—do patterns of discontinuity appear. The fossil record still shows discontinuity surrounding clusters of continuity that probably approximate created kinds. The findings of these statistical analyses fit very well with the expectations of creationist taxonomy, as illustrated by Wise’s idea of a “neo-creationist orchard” (Wise 1990). All of life is not related by common ancestry, but some groups of organisms are descended from common ancestors. Both birds and dinosaurs are categories of multiple holobaramins, grouped under the same name because of shared anatomical features, but not on the basis of common ancestry. The debate about whether birds evolved from dinosaurs becomes less important from this standpoint of baraminology because neither “birds” nor “dinosaurs” is a group of animals connected by common descent. While the words themselves are

still meaningful, in a creationist way of thinking the terms “bird” or “dinosaur” can only describe shared characteristics among similar animals within a greater created pattern, not common ancestry. While an evolutionist would use both the terms *birds* and *ducks* to refer to common ancestry, creationists view the latter as a group that probably does share a common ancestor (an original created duck kind), while we decidedly reject the idea that all of the former group (birds) evolved from a common ancestor.

So, we have three perspectives about taxonomic language. From an evolutionary perspective, taxonomic language ideally reflects common ancestry, hence the current drive for names to reflect monophyletic groups. From an outdated creationist perspective (when many creationists ascribed to species fixity and thought that “created kind” equaled “species”), the conclusion could be reached that all taxonomic language was merely utilitarian, since no two species were actually related. From a new creationist perspective, taxonomic language can—depending on the group of organisms addressed—describe either ancestral relationships (e.g. cats or penguins) or common design patterns (e.g. mammals, birds, or vertebrates). Hence, a truly creationist way of thinking about taxonomy, similarities, and relationships now requires us to carefully and clearly define our terms. We must ask what the terms *birds* and *dinosaurs* actually mean, rather than reflexively say that “birds” are—or are not—“dinosaurs.” Since the features that define mammals are present in bats, but bats also have certain unique features that no other mammals have, we classify bats as a subgroup of mammals, even though we are confident bats do not share a common ancestor with other mammals. Since the features that define theropod dinosaurs are present in birds, but birds also have certain unique features that no other theropod dinosaurs have, birds could be considered a type of dinosaur.

To give a parallel example to that of dinosaurs and birds, this way of analyzing terminology from a baraminological, creationist perspective frees us when discussing human taxonomy. Some creationists feel uncomfortable using the scientific terms “primate” or even “mammal” to refer to humans. Viewed from an understanding of created kinds, though, these terms need cause no concern. We can fairly say that humans are both mammals and primates as long as we understand and clarify that these terms refer to common design patterns and features shared with all other creatures in these groups.

While phrases such as “humans are primates” or “birds are dinosaurs” may make us feel uncomfortable, they are really no more or less problematic than, “monkeys are primates,” “stegosaurus are dinosaurs,” or “frogs are amphibians.” All these are valid as long as they reflect a real, observable pattern (i.e. the phrase, “humans are frogs” is not true). All these phrases legitimately refer to common design patterns, and none refer to common ancestry. None of these phrases necessarily represent compromise with or acceptance of evolution, because we use them in a distinctly different, clearly articulated sense.

Interestingly, using broader-scale taxonomic terms (above the level of the created kind) to refer to common design instead of ancestry reclaims the sense in which many of these terms originated. Early naturalists who were creationists coined many of the taxonomic

terms we now use (Linnaeus himself classified humans as primates), and the later use of these terms in a Darwinian sense does not make them inappropriate for creationists today. Many creationists negatively react against taxonomic terms and concepts because they see them as evolutionary and incompatible with Scripture, but if we accurately understand the origins of these ideas, then we will see that such thinking can give us a deeper appreciation and understanding of God's design patterns in the creation.

3. Folk Taxonomies, Scientific Taxonomy, and Scripture

The origins of classification pre-date modern, scientific taxonomy. Throughout history, all human societies have not only named animals and plants, but also coined classificatory terms to group them into categories and hierarchies. Ethnobotanists and ethnozoologists examining folkbiology of tribal cultures in the last century were consistently surprised to find that people groups then perceived as primitive had extremely detailed knowledge of flora and fauna, as well as conceptual structures for classifying them (Berlin 1992). From a creationist perspective--considering that the first task of the first human was naming the animals in Eden--it is not surprising that prescientific cultures worldwide intensely observed animals and produced ordered systems of classification. Dubbed "folk taxonomies," these ethnic means of categorizing organisms created some debate among researchers. Those from a relativist, utilitarian perspective on ethnobiology viewed folk taxonomies as artificial, culturally-isolated, human attempts to impose order on nature. However, completely unrelated cultures were found to produce folk taxonomies with strong parallels. Ethnobiologists such as Brent Berlin deduced that, although produced by humans acting in cultures, folk taxonomies are not purely relativistic, cultural constructs. The parallels between cultures exist precisely because nature is not culture. Folk taxonomy arises from a human attempt to classify something outside of, but interacting with, human culture. Furthermore, folk taxonomies are not strictly utilitarian, focusing merely on creatures that are important to humans. More types of plants and animals are described than have utility for humans, although utilitarian purposes may guide classification. Folk taxonomy, at its core, represents a basic human cognitive desire and innate drive to group and categorize a real natural order. Humans do not create this order; they simply try to describe it (Berlin, 1992).

Folkbiology classifications, whether ancient or recent, are not scientific taxonomy in the modern sense. However, folkbiology classifications usually differ little from scientific taxonomy when distinguishing lower-order taxa. Ethnobiologists like Ernst Mayr and Jared Diamond discovered that a one-for-one correspondence often existed between modern species names and New Guinea tribes' folk generics (their basic unit name for a "natural kind" of bird, like our English *robin* or *mockingbird*) (Bulmer and Tyler 1968). Folk taxonomies have even revealed distinctions unknown to science. For instance, the Karam tribe in New Guinea used two names, *kosoj* and *wyt*, to refer to one species of frog, *Hyla becki*. Further research demonstrated that these were actually two, similar species, *Hyla* (now *Litoria*) *micromembrana* and *H. modica* (Bulmer and Tyler 1968). In contrast to lower-order categories like species, higher-order folk taxonomic groups have less correspondence to scientific taxonomic categories. While

modern, scientific taxonomists classify animals based on anatomy, genetics, and inferred ancestry, folk taxonomies tend to group animals into higher-order classes based on factors such as general appearance, environmental niche, behavior, and relation to humans. For instance, the Ndumba society of New Guinea includes bats and birds in the same category, *kuri* (Berlin, 1992, p. 167). Some tribes in New Guinea classify cassowaries (giant, flightless birds) using the same higher-order category as other birds. However, the Karam society of New Guinea uses the term *yakt* to encompass bats and all other birds, but does not include the *kobtiy*, or cassowary, in this *yakt* category for a variety of reasons, both anatomical and cultural (Bulmer 1967). The Hebrew names for animal groups are similarly an example of functional classification. English Bibles usually translate the Hebrew word '*oph*' with the English *bird*. However, the Hebrew word translated to English as *bat*, '*atalleph*', is included in the category '*oph*' (Leviticus 11:13-19). The Hebrew '*oph*' is not equivalent to any of the English cultural or modern, scientific terms, for birds. Rather, '*oph*' refers to a category of winged, flying creatures that would have included our English terms *birds*, *bats*, *pterosaurs*, and some flying insects (Lightner 2010).

Although folk taxonomies are not strictly scientific, that does not mean that they are wrong or contrary to science. They were created for an entirely different purpose than scientific taxonomy. Folk taxonomies are part of each culture's language, and are very useful for their purpose, the everyday communication and description of nature in a specific society and language. Even today, we will use non-taxonomic terms to describe functional, behavioral, or environmental roles (e.g., planktonic, herbivorous, or domesticated). Similarly, the divisions used to describe created animals in Genesis 1-2 do not divide precisely along our modern taxonomic categories (e.g., "beasts of the field" and "creeping things"). At least two attempts were made to map Hebrew words to scientific, taxonomic terms, and generate a technical, taxonomic system from Genesis (Berndt 2000; Klenck 2009). But these anachronistically and rather arbitrarily shoehorned already-dated Linnaean terms into Hebrew words without providing Scriptural evidence that the creation account was intended to provide a scientific taxonomy. A later study (Lightner, 2010) noted that the words used in Genesis for animal groups appeared to overlap in meaning, referring to general groups instead of strict divisions.

Since Genesis does not provide a scientific taxonomy, it is appropriate to develop our own as long as we maintain the framework provided by Scripture (for instance, no common ancestry among higher-order taxa). Because the functional Hebrew folk taxonomy in Genesis and modern, scientific, creationist taxonomy are two different, independent systems, they do not conflict. It is as inappropriate to claim that the Hebrew categories in Genesis 1-2 prove scientific taxonomy to be wrong as it would be to claim that modern, scientific taxonomy proves Genesis 1-2 to be wrong.

Likewise, it would be inappropriate to point to the creative order in Genesis as in any way conflicting with or governing creationist taxonomy. Some creationists have emphasized that birds were created on the fifth day of the creation week and dinosaurs on the sixth day (e.g., Sarfati 2000). By implication, Scripture forbids classifying birds and theropods as members of the same group.

However, the only valid inference from Scripture is that any kind created on the fifth day does not share common ancestry or evolutionary history with a kind created on the sixth day. Since creationist taxonomy is a matter of higher-order design patterns—not of evolution—it is acceptable to categorize animals created on different days as members of a larger group. All creationists already classify flying bats, which were presumably created on the fifth day, as mammals along with terrestrial ungulates and carnivorans, which were presumably created on the sixth day. Also, the species that later diversified from the created kinds in Genesis are not necessarily bound to their original behavioral category. The original created kind that was ancestral to today's flying swamphearts (e.g. *Porphyrio martinicus*) was doubtless created on the fifth day. However, after creation some members of same genus (e.g. *Porphyrio hochstetteri*) became flightless. Likewise, some terrestrial theropod dinosaurs may be secondarily flightless descendants of flying or gliding theropods (Boris 2014; Paul 1988; Paul 2002; Senter, et al. 2012), which would indicate they were likely created on the fifth day.

The development of modern, scientific taxonomic systems was fostered by the realization that nature displayed complex patterns beyond simple classification by environmental niche, behavior, or even gross morphology. Over time, naturalists began to realize that classifying animals according to whether they lived in the ocean or on land, for instance, only reflected part of the observable data in nature. Animals classified in one group sometimes shared features with animals in an entirely different group. For instance, it is widely known that cetaceans like whales and dolphins were once classified as “fish.” However, it seems inaccurate to portray scholars as thinking that whales were “fish” in the modern sense of the term. As far back as the 4th century B.C., Aristotle recognized that cetaceans possessed hair, breathed through lungs instead of gills, gave live birth, produced milk for their young, and had skeletons more similar to land mammals (Romero 2012). During the Renaissance, naturalists also discovered that cetaceans' four-chambered hearts, brains, and limb bones had more in common with land mammals than with fish (Romero 2012). Still, almost everyone called them “fish” or at least grouped them with fish in their books, since whales and fish shared the same environment. Not until the invention of modern, rank-based taxonomy by Carolus Linnaeus were whales finally classified as mammals (Romero 2012). It was not exactly that naturalists before Linnaeus mistakenly believed that whales were true fish. They just had a simpler classification system that ordered animals using less data, and their classification system had to be adjusted as more information became available.

In the 1700s, Linnaean taxonomy finally recognized these deeper relationships between animals by classifying them with a rank-based system, organized by common anatomical features instead of merely gross morphology or environment. Linnaeus gave us not only consistent, uniform names for animals, but a way to categorize and describe similarities between them. A dolphin, a swordfish, and an ichthyosaur (an extinct, marine reptile) look externally similar and have (or had) similar lifestyles. While older approaches might have grouped them together, taxonomy from a Linnaean perspective, requires that we group dolphins with mammals and ichthyosaurs with reptiles because—at a fundamental level—they

share many more anatomical similarities with their respective groups than with fish.

Linnaeus described life as a nested hierarchy, with animals in a series of progressively smaller “boxes.” Contemporaneously with Linnaeus, Peter Simon Pallas, a German-Russian naturalist, was likely the first to describe (but not illustrate) the idea of a “tree of life” showing affinities between various groups of animals and plants. Pallas noted (Bednarczyk 2010):

But the system of organic bodies is best of all represented by an image of a tree which immediately from the root would lead forth out of the most simple plants and animals a double, variously contiguous animal and vegetable trunk; the first of which would proceed from mollusks to fishes, with a large side branch of insects sent out between these, hence to amphibians and at the farthest tip it would sustain the quadrupeds, but below the quadrupeds it would put forth birds as an equally large side branch.

Pallas was no Darwinist: he not only lived long before Darwin, but also believed in creationism, the fixity of species, and no environmentally-influenced variation (Bednarczyk 2010; BMNH Last Edited 2013).

In 1801, French botanist Augustin Augier, who appears to have been a creationist, portrayed plant relationships using a tree. In the 1800s, Edward Hitchcock and Louis Agassiz used tree diagrams to show the history of all life and of fish, respectively. Both of these men, while not young-earth creationists in the modern sense, were vocal anti-evolutionists. Before and after the publication of *Origin*, these creationists portrayed current biological diversity and the fossil record using tree-like patterns that they believed to be the work of God. Darwin and other transmutationists before and after him did not create the concept of life having a hierarchical or even tree-like pattern. Rather, they looked at a pattern of life that many scientists perceived and provided a new explanation for the origin of that pattern. And, as Darwinism became ascendant, creationists abandoned their portrayal of life as a tree, evidently concerned that their iconography had been taken over by evolutionists (Archibald 2008).

In today's cultural setting, most creationists assume that portraying life using a branching pattern is an evolutionary concept. This is understandable, since the primary use of “trees of life” for over a century has been to illustrate a Darwinian, phylogenetic view of all organisms connecting to a common ancestor. In reality, it is anachronistic to treat the concepts of nested hierarchies and a tree-like pattern to life as Darwinian, since both ideas preceded Darwin and were invented by creationists to describe the pattern of creation.

But many creationists have already recognized this. For instance, Walter ReMine, the creator of discontinuity systematics, noted:

Any system of objects can be forcibly classified into a nested hierarchy. Some systems do not have to be forced, rather they display a nested pattern with clarity without having to be coerced. Life has such a pattern. There are no tetrapods that are not based on the vertebrate body plan. There are no amniotes that are not based on the

tetrapod body plan. There are no mammals that are not also amniotes. These are familiar examples, and many more can be given. They are powerful generalizations. Life is like nested Chinese boxes of subsets within subsets within subsets. Life is comprised of nested similarities. This significant pattern must be explained (ReMine 1993, p. 344).

Looking at the history of thinking on the pattern of life, Wood and Murray (2003, p. 30) noted:

In like manner, a hierarchical pattern of life also appears to be a legitimate description of organisms. The hierarchy was strongly advocated by Sir Richard Owen, who interpreted it as a revelation of God's design plan. Later, Darwin infused the hierarchy with an evolutionary meaning, transforming the design plan into a genealogical tree. Although we reject the historical interpretation of the evolutionary tree, the hierarchical pattern has a degree of authenticity to it.

The idea that life forms a pattern, perhaps as a nested or reticulate (netted) hierarchy is quite commonly accepted by young-earth creationist biologists and paleontologists who actively use baraminological methods to examine living and fossil species (Wise 1998). Even those creationists who have reached different conclusions on the topic of birds and dinosaurs recognize the pattern and its non-Darwinian implications:

Cladistics demands a nested pattern, and the fossil evidence fits into such a pattern relatively well, especially for higher taxonomic categories. However, neither evolution in general nor descent with modification in particular demand a nested pattern. Moreover, the nested pattern can be explained at least as well in a common design paradigm (Doyle 2011, p. 36).

Therefore, rather than criticizing Darwinian interpretations of this pattern of life or rejecting the idea that life has a higher-level pattern, creationists would profit from developing better methods to understand the pattern and make predictions in a creationist framework. Further efforts to model-build by quantifying the pattern of life and developing better understanding of its larger structures are an important area for future research.

Viewing the dinosaur-bird debate through the lens of folk and scientific taxonomies, and their relation to Scripture, allows us to resolve most of the issues that have bothered creationists in the past. First, we no longer have to be concerned that the phrase, "birds are dinosaurs" conveys any evolutionary implications. Since nested hierarchies and branching taxonomic trees were concepts developed by creationists to describe God's creative pattern, we can use the terminology associated with them. We have no problem recognizing that bats or whales are mammals, even though we do not believe that bats or whales share a common ancestor with zebras or shrews. An evolutionist will say, "birds are dinosaurs" in the sense that birds evolved from dinosaurs, but we can say that "birds are dinosaurs" in the sense that birds are a subgroup of dinosaurs in a larger pattern of God's creation, and that they are not all related through common descent. Whether we say the phrase or not, we can recognize patterns in the fossil record, while still

disagreeing with evolutionists about the cause of those patterns. Secondly, this new perspective exposes how our own Western folk taxonomies have biased our understanding of the larger patterns in God's design. When we think about tetrapods, our Western mind neatly divides them into four groups—amphibians, reptiles, birds, and mammals—following the pattern we see among extant animals. However, when we try to impose this paradigm on the fossil record, we run into issues. There are animals that seem to be neither reptile nor mammal (therapsids), neither reptile nor bird (feathered dinosaurs), neither amphibian nor reptile (diadectomorphs), and neither fish nor amphibian (non-tetrapod tetrapodomorphs). Thus, although the four-division system of tetrapods works very well today, it would not have been so useful before the Flood. In fact, it is likely that if all of these extinct animals were alive today, we may not have divided vertebrates into these exact categories. When we are determined to fit all animals into the four-part tetrapod scheme simply because we think the animals of the past can only belong to the groups existing in the present, we are inadvertently operating in a way similar to uniformitarians by saying that the past must conform to the present. Instead, we need to recognize that our current world is depauperate when compared to the pre-Flood world. This new understanding allows us to recognize that there is no reason why there cannot be feathered dinosaurs or "non-mammalian synapsids." The fossil record reveals to us that God's creation is much richer and more complex than we could have predicted given the animals that currently exist.

CONCLUSIONS

From our survey of feathered dinosaur species and our statistical baraminological analyses, we reached several conclusions. First, many species of dinosaurs were indisputably feathered. The available fossils have moved us permanently beyond questioning whether some dinosaurs were feathered and onward to interpreting the implications of feathered dinosaurs. Second, among the coelurosaurs, the major group of feathered dinosaurs, patterns of discontinuity and continuity indicate that there were likely multiple holobaramins of feathered dinosaurs. Third, the holobaramins of feathered dinosaurs are generally discontinuous with avialans, the group that includes living birds. The second and third points above once again disprove Phil Senter's (2010) idea that baraminology should make creationists classify Mesozoic birds and many coelurosaurs as a single created kind. Not only do feathered dinosaurs not share common ancestry with extant birds, but the major groups of feathered dinosaurs are apparently not even related to one another by common descent. So, feathered dinosaurs, modern birds, and Mesozoic birds are not three different created kinds of animals, but rather three groupings with multiple created kinds per group, and the old dichotomy of bird versus dinosaur is unhelpful and incorrect. Birds could rightly be viewed as a specialized type of dinosaur without implying birds evolved from dinosaurs. Much of this confusion about the similarities between birds and dinosaurs in creationist circles actually stems from the misapplication of our Western folk taxonomy of a four-division Tetrapoda onto the past. Forcing fossil specimens to be either "bird" or "dinosaur" neglects the complexity of the design patterns among these kinds of animals and can mask God's glory, which He determined to display through them.

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APPENDIX

For BDC Plots: Black squares indicate significant positive correlation, whereas open circles indicate significant negative correlation.

For MDS Plots: Colors: red – non-coelurosaur theropod; orange – Dromaeosauridae; yellow – Troodontidae; light green – Avialae; pink – Oviraptorosauria; turquoise – Therizinosauria; green – Alvarezsauridae; blue – Ornithomimosauria; brown – “basal” Coelurosauria; purple – Tyrannosauroidae.

BDC and MDS plots on the following pages (Figs. 66-75).

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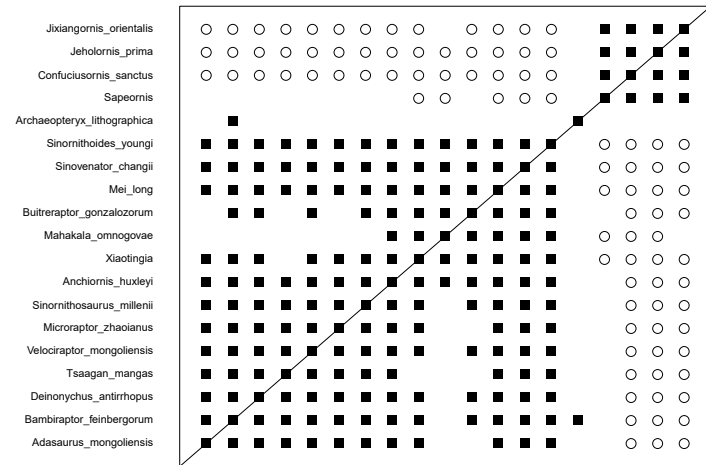


Figure 66. Resulting BDC plot after removal of *Aurornis*, *Balaur*, *Troodon*, and *Zanabazar* (all <0.32 TRC) from the paravian subset analysis of Brusatte et al. (2014).

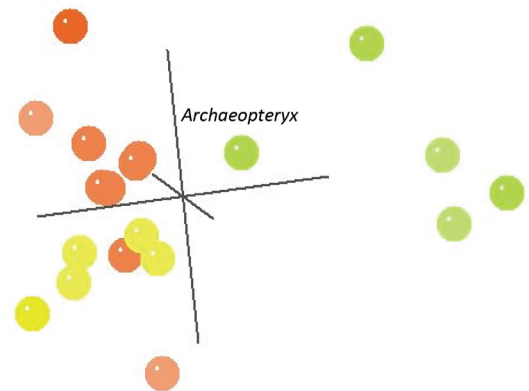


Figure 67. Resulting MDS plot after removal of *Aurornis*, *Balaur*, *Troodon*, and *Zanabazar* (all <0.32 TRC) from the paravian subset analysis of Brusatte et al. (2014).



Figure 68. Initial BDC analysis of the Lee et al. (2014) dataset including *Meleagris* and *Ichthyornis*.

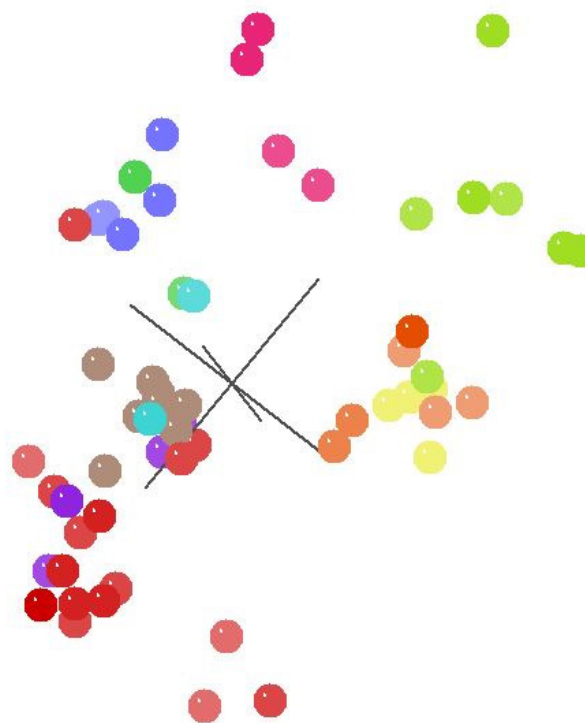


Figure 69. Initial MDS analysis of the Lee et al. (2014) dataset including *Meleagris* and *Ichthyornis*.

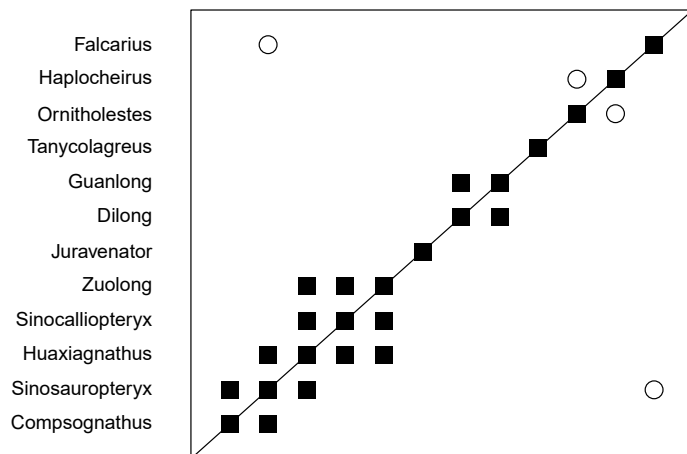


Figure 70. “Basal” coelurosaur subset BDC analysis of the Leet et al. (2014) dataset (12 taxa, 304 characters).

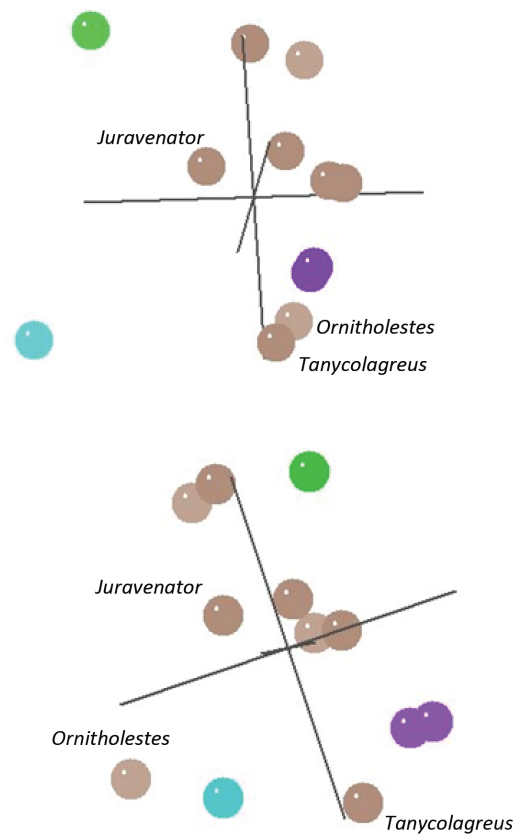


Figure 71. “Basal” coelurosaur subset MDS analysis (two views) of the Leet et al. (2014) dataset (12 taxa, 304 characters).

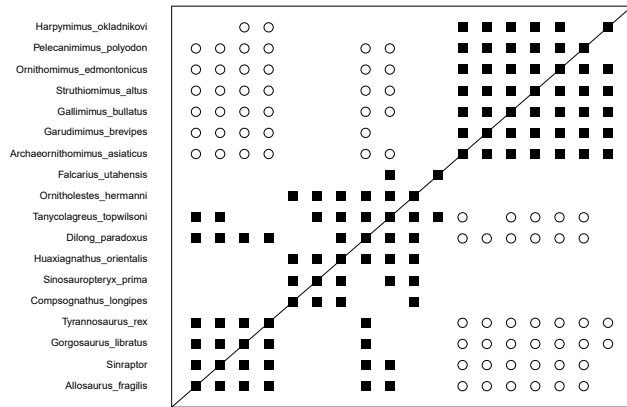


Figure 72. Resulting BDS plot after removal of *Erlikosaurus* and alvarezsaurids from the non-pennaraptoran subset analysis of Van der Reest and Currie (2017) (18 taxa, 155 characters).

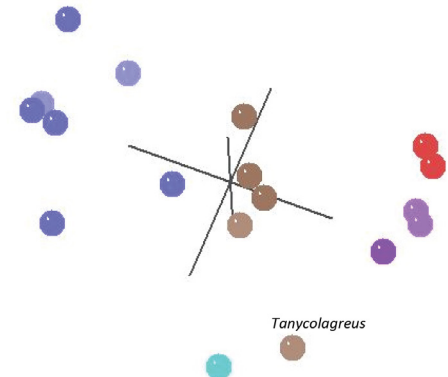


Figure 73. Resulting MDS plot after removal of *Erlikosaurus* and alvarezsaurids from the non-pennaraptoran subset analysis of Van der Reest and Currie (2017) (18 taxa, 155 characters).

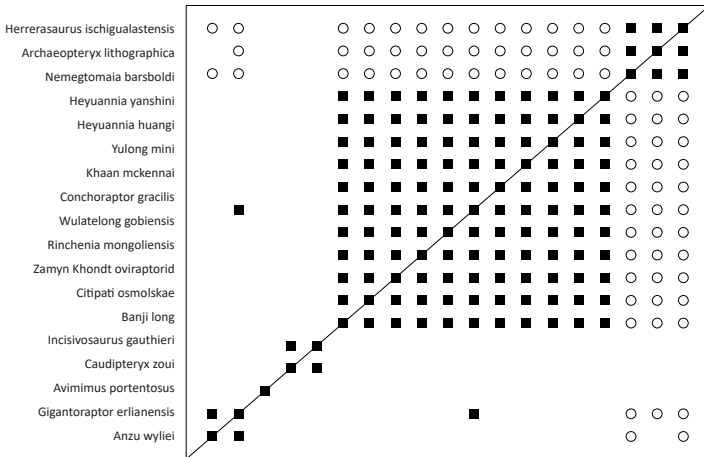


Figure 74. BDC plot from Lamanna et al. (2014) at 0.3 TRC.

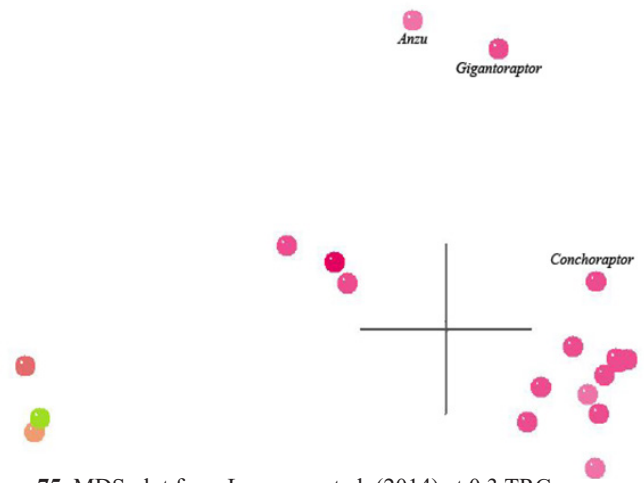


Figure 75. MDS plot from Lamanna et al. (2014) at 0.3 TRC.