EVOLUTIONARY DYNAMICS OF AVIAN AND NON-AVIAN LIMB MORPHOLOGY

BY

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THESIS

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ABSTRACT

Variation of phenotypic traits and covariance among them strongly controls the strength and direction of natural selection. These patterns are characterized as phenotypic covariance structure: the degree to which traits vary in coordinated fashion. The quantitative analysis of covariance structure, and particularly how it changes over evolutionary time, will reveal how genetic variation translates into phenotypic variation, the sources of and limits to variation, and ultimately a mechanistic understanding of phenotypic evolution.

Traits may covary due to several possible intrinsic (e.g., two traits influenced by the same gene) or extrinsic factors (e.g., two traits of the same functional apparatus). Flight styles vary greatly in birds from flightless birds with little or no functional influence to strong flappers with great functional influence. This variation allows specific tests of the expected magnitude of functional influences on patterns of integration. In chapter one of this thesis, we analyzed the covariance structure of the fore and hind limbs of adult and embryonic chickens, ducks, and cowbirds to test the following evolutionary hypotheses: 1) If patterns of covariance are determined predominantly by intrinsic factors, but these factors evolve over time (but not in relation to function), closely related species will have more similar matrices than when compared with distantly related species, meaning the similarity of variance/covariance matrices among species is a function of phylogenetic “distance”; 2) If patterns of covariance are determined predominantly by function (i.e., natural selection for a function), functionally similar taxa will be more similar than would be expected given their phylogeny; 3) If patterns of covariance are determined by a complex relationship between intrinsic and extrinsic factors, the similarity of variance/covariance matrices will show no pattern with respect to phylogeny or function; 4) If extrinsic influence dictates ontogenetic appearance of patterns of trait covariance and this is done

with the application of function during ontogeny, patterns of covariance seen in the adult birds will appear later in ontogeny; 5) If intrinsic influence dictates ontogenetic appearance of patterns of trait covariance and selection for functional ability has influenced the developmental process, patterns of covariance seen in the adult birds will appear early in ontogeny.

We found that the covariance structures of adult chickens, ducks, and cowbirds do not differ significantly and therefore the developmental processes in the limbs of these birds are conserved.

The origin of birds and associated transition to flight fundamentally changed fore- and hind limb function. As the forelimbs became dedicated to locomotion, the biomechanical requirements of powered flight likely placed substantially different selective regimes on the skeletal elements of the limbs. Specifically, it has been shown that the relative sizes of the humerus an ulna are closely related to flight style in various clades of birds. This pattern suggests a tight link between locomotor function and wing skeletal morphology, and potentially a constraint on the evolution of these elements. In contrast, non-avian theropods and flightless birds likely had more relaxed biomechanical constraints on these elements, and therefore the potential for greater evolutionary lability.

In chapter two of this thesis, we tested whether the relationships among limb elements show different evolutionary dynamics in flying and flightless theropods (including birds). We used published databases of element lengths supplemented with measurements from the literature. We also constructed a composite phylogeny including theropods and both extant and extinct birds. Using these data and this tree, we statistically tested whether the rates and patterns of evolutionary correlation between the humerus and ulna differ between flying and flightless species. Specifically, we tested four models using a likelihood-ratio test and AIC: 1) flying and flightless theropods shared common rates and evolutionary correlations between the humerus and ulna, 2) different rates, but a shared correlation, 3) shared correlation, but different rates, and 4) different rates and patterns of correlation.

The resulting evolutionary rates seem to reflect evolution of body mass, particularly in non-bird flightless theropods. Flightless birds show higher evolutionary correlations I both limbs, which may reflect the diversity of characteristic morphologies required by different flight styles and hind limb functions in flying theropods.

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CHAPTER 1

EVOLUTIONARY DYNAMICS OF THE LIMBS OF BIRDS AND THEROPOD DINOSAURS: TESTING THE INFLUENCE OF FUNCTIONAL CONSTRAINT

Introduction

The origin of flight in birds is one of the major locomotion transitions in evolutionary history. Flight allowed birds to exploit novel ecological niches, and ultimately led to their great radiation. Flapping flight also constituted a fundamental change in the roles that the fore and hind limbs played in locomotion. Ancestrally, theropod dinosaurs were bipedal, leaving their forelimbs free from any functional role for locomotion. At the origin of flight, aerial locomotion became a primary function of the forelimbs, and the locomotory requirements of the hind limbs was somewhat reduced (Padian 2009, Hackett et al. 2008, Gauthier 1986). These functional differences imply a change in the dynamics of fore and hind limb evolution in flying birds.

Studies of the diversity of hind limb element proportions demonstrate that flying birds occupy substantially greater morphospace than their non-flying dinosaur ancestors (Gatesy and Middleton 1997; Benson and Choiniere 2013), corresponding to the greater diversity of avian hind limb functions (e.g., prey capture, perching, grasping, climbing, swimming; Abourachid and Hofling 2012; Pennycuick 1986; Butler 1991). This greater morphological diversity is consistent with the hypothesis that forelimb-powered flight eased functional constraints on their hind limbs, thereby increasing their evolutionary lability.

This simple notion of function leading to evolutionary constraint does not appear to hold for the forelimb. Previous studies demonstrate that flying birds have a greater disparity of forelimb element proportions than non-flying theropods, despite the functional requirements imposed by aerial locomotion (Middleton and Gatesy 2000; Benson and Choiniere 2013). This apparently contradictory pattern suggests either the requirements for flight are not sufficient to constrain the evolution of limb element proportions, or that this diversity reflects functional (and therefore morphological) variation among birds with distinct flight styles (Middleton and Gatesy 2000). Despite the fact that feathers comprise much of the aerodynamic surface of bird wings, the proportions of limb skeletal elements largely determine planform and wing deformations during flight (Nudds and Dyke 2010). Accordingly, several studies demonstrate skeletal measurements robustly discriminate birds with different flight styles and behaviors (Nudds and Dyke 2010; Nudds 2007; Habib and Ruff 2008; Simons 2010, Wang et al., 2011) (Figure 1) and show a large variation among birds (Dececchi and Larsson 2013; Zeffer et al. 2003), which suggests a tight link between locomotor function and wing skeletal morphology. This suggests that the greater forelimb disparity of flying birds relative to their non-flying ancestors reflects adaptive diversification toward novel functions.

However intriguing, patterns of disparity are not sufficient to reveal underlying evolutionary dynamics, and different evolutionary processes can lead to indistinguishable patterns of disparity (e.g., Foote 2000). Functional constraint makes specific predictions about evolutionary correlation. In this study, we statistically test whether the rates of evolution and patterns of evolutionary correlation between the fore and hind limbs and between the major elements within the limbs differed between flying and non-flying taxa. Some recent studies focus on rates or magnitudes of morphologic change of theropod limbs during the origin of birds (e.g,. Clarke and Middleton 2008; Dececchi and Larsson 2009, 2013; Benson and Choineire 2013), but our emphasis on the evolutionary correlation among limb elements allows a more specific test of functional constraint hypotheses.

If the biomechanical requirement of flying constrained forelimb element evolution and released constraint on hind limb evolution, then we expect 1) lower rates of forelimb element evolution in flying versus non-flying theropods; 2) higher rates of hind limb element evolution in flying theropods versus non-flying theropods, as their functions diversified beyond terrestrial locomotion (e.g., prey capture, perching, etc.); 3) tighter evolutionary correlation among forelimb elements in flying versus non-flying theropods; 4) no change in the evolutionary correlation among hind limb elements.

Methods

Measurements

We characterized the forelimbs using lengths of the humerus, radius, and carpometacarpus in birds or metacarpal II in earlier theropods (Figure 2 a,b), and the hind limbs using the femur, tibiotarsus, and tarsometatarsus in birds or metatarsal III in earlier theropods (Figure 2 c,d). Lengths of these elements have been used to represent the major limb elements in many previous studies (Gatesy and Middleton 1997; Middleton and Gatesy 2000; Bell et al. 2011; Dececchi and Larsson 2013). We used published length measurements of these elements (Gatesy and Middleton 1997; Middleton and Gatesy 2000; Dececchi and Larsson 2013; Benson and Choiniere 2013) to construct a data set including 654 extinct and extant theropod taxa. All individuals were adults and all major families were represented. We also determined from the literature whether each species was capable of powered flight (Ponton et al. 2007). The measurements and flight ability appear in Appendix A.

Phylogeny

We constructed a composite phylogenetic tree using Mesquite software (Madison and Madison 2011) representing the evolutionary relationships among the 654 taxa for which we had measurement data (Figure 3). This phylogeny was constructed using multiple published trees as sources (Appendix B), however it is largely based on the tree constructed by Hackett et al. 2008. Where the evolutionary relationships were highly debated or unknown, polytomies were left in the tree.

We scaled the branch lengths of the tree with respect to time using a two-stage procedure to first incorporate fossil occurrence data from the Paleobiology Database (paleodb.org), and then divergence dates of selected nodes from published molecular-phylogenetic estimates.

First, we compiled stratigraphic ranges of all taxa with fossil occurrence data in the Paleobiology Database. For each taxon, we drew first-occurrence dates from a random uniform distribution based on the uncertainty around each. We then assigned divergence dates to nodes based on their oldest descendants, which we will here refer to as the "fossil date." Extant taxa without fossil occurrences were assigned an age of 0.0Ma. To prohibit zero-length branches from nodes to their oldest descendants, we then arbitrarily added 0.5My to the age of each internal node. Because the "fossil date" is a minimum estimate of its age, we performed a smoothing procedure that randomly adjusted the ages of nodes, which we will call "revised dates." We began this procedure by first drawing the "revised" date of the root node from a uniform distribution between its "fossil date," (i.e., the age of the oldest taxon in the tree) and an arbitrarily assigned date 10My older than that. We then worked from the root to the tips of the tree, adjusting the age of each descendant node by drawing from a random uniform distribution between its "fossil date" and the "revised date" of its direct ancestor.

Second, we selected particular nodes for which we incorporated divergence dates from recent molecular-phylogenetic studies. These divergence dates and their references are shown in Appendix C. For these specific nodes, we drew their dates from a random uniform distribution from within the published errors of the estimates. Because we did this for only a small subset of nodes, some of these nodes then became older than the fossil-based “revised dates” of their ancestral nodes. Accordingly, after all molecular-based dates were applied, we adjusted the node ages of all internal nodes so that each ancestor was at least 0.5My older than its descendant nodes, and then reapplied the same smoothing procedure described above to generate the “revised” ages of all nodes.

Several evolutionary relationships within theropod phylogeny are uncertain, and because the fossil- and molecular-based divergence dates are not known without error. To accommodate this uncertainty, we performed 100 pseudoreplicates of all analyses described below for forelimb data and 56 pseudoreplicates for hind limb data. For each pseudoreplicate analysis we generated a tree by randomly resolving the phylogeny to a completely bifurcating tree, and then reapplying the described dating procedures.

Evolutionary Model Tests

We used the method of Revell and Collar (2009; see also Revell and Harmon 2008) to determine if the evolutionary dynamics of limb elements differed between flying and non-flying theropods. The evolutionary rate matrix, **R,** consists of a set of evolutionary rates of individual elements along the diagonal, and correlations among elements in the off-diagonal cells. The simplest null hypothesis is that a single set of parameters, $\mathbf{R}_{\mathbf{single}}$, applies to the entire tree (irrespective of flight). The more complex alternative hypothesis is that flying and nonflying each have distinct sets of parameters, $\mathbf{R}_{\mathbf{flying}}$ and $\mathbf{R}_{\mathbf{nonflying}}$. We used likelihood ratio tests (LRT) to statistically assess which of these hypotheses best fit the data for fore and hind limbs, separately. All analyses were performed in R using the phytools package (Revell 2012). Normal distributions of the differences between the rates of evolution and evolutionary correlations of flying and non-flying theropods were calculated for fore and hind limbs separately. P-values of the difference distributions of evolutionary rates and evolutionary correlations were calculated using a z-test. All p-values can be seen in Appendix D.

Results

Rates of Evolution

Forelimb

The majority of repetitions conducted showed that flightless theropods exhibit a higher rate of evolution for both the humerus and carpometacarpus than flying theropods (figure 4-5 and table 1), but is only significantly higher for the carpometacarpus. Flying theropods exhibited a higher rate of evolution for the radius than the flightless theropods, but not significantly higher (P-value of 0.520). In flying theropods, the carpometacarpus had a significantly lower rate of evolution than the humerus and radius. In flightless theropods, the carpometacarpus had a significantly higher rate of evolution than the radius and humerus.

Hind limb

Flightless theropods exhibit a higher rate of evolution for all elements of the hind limb than flying theropods (Figure 6-7 and Table 2) however the tarsometatarsus did not have a significantly higher rate in flightless theropods (P-value of 0.107). In flying theropods, the tarsometatarsus showed the highest rate of evolution compared to the tibotarsus and femur, which had the second and third highest rates respectively. In flightless theropods, the femur showed the highest rate of evolution followed by the tarsometatarsus and tibiotarsus however the rate of evolution for the tibiotarsus was not significantly higher than the rate for the tarsometatarsus (P-value of .050) and the femur did not have a significantly higher rate than the tarsometatarsus (P-value of 0.232).

Evolutionary Correlations

Forelimb

Flightless theropods as show tighter evolutionary correlations than flying theropods for all three pairwise combinations of forelimb elements, relative to those of flying theropods (Figure 8-9 and Table 3), but no correlations were significantly tighter (P-values of 0.420, 0.110, and 0.170). For flying theropods, the correlation of the humerus to radius was the tightest, followed by the correlation of the radius to carpometacarpus, which in turn was followed by the humerus to carpometacarpus. The correlation of the radius to carpometacarpus was tightest for flightless theropods, followed by the correlations of the humerus to carpometacarpus and humerus to radius respectively. The correlation of the radius to the carpometacarpus was not significantly tighter than the correlation of the humerus to the carpometacarpus (P-value of 0.140).

Hind limb

Flightless theropods have tighter evolutionary correlations among all three pairwise combinations of hind limb elements, relative to those of flying theropods (Figure 10-11 and Table 4). For flying theropods, the correlation of the tibiotarsus to the tarsometatarsus was significantly tighter than the correlation of the femur to the tibiotarsus and the correlation of the femur to the tarsometatarsus. For flightless theropods, no correlations were significantly tighter than any others (P-values of 0.286, 0.125, and 0.054).

Discussion

Rates of Evolution

We expected that the rate of evolution in the forelimb of flying theropods would be lower than that of flightless theropods, because flight necessitates specific biomechanical requirements. Although there are various degrees of flight strength and maneuverability (i.e., flight styles), the wing skeletal elements of all flying theropods must be constrained within the parameters required by the biomechanics of flight. We found this to be true in the humerus and carpometacarpus, and found the radius to have the roughly the same rate of evolution in both fliers and non-fliers.

We expected the evolutionary rates of the hind limb elements to be greater in flying theropods than in non-flying theropods. We expected this because of the hind limb diversity seen in birds (Gatesy and Middleton 1997). With forelimbs as a primary mode of locomotion, some of the functional constraint due to locomotion was relaxed, allowing for variation (Gatesy and Dial 1996; Gatesy and Middleton 1997; Hunter 1998; Wainwright 2007; Benson and Choiniere 2013). In contrast to this, we found the rates of evolution in all elements of the hind limb of non-flying theropods to be greater than those of flying theropods.

The limb element lengths were not standardized for size in this study. Evolutionary rates of the elements therefore include the evolution of body mass. Our predictions focused on element length relative to whole limb length (which may be closely related to function; Benson and Choiniere 2013) so it is not surprising that the resulting rates of evolution do not match our predictions well. It is also unsurprising that non-flying theropods were found to have higher evolutionary rates than flying theropods for all limb elements, because the body mass is extremely variable among non-flying theropods (Christiansen and Farina 2004). Benson and

Choiniere (2013) calculated rates of evolution for fore and hind limb proportions of Mesozoic theropods (flying and non-flying) after the limb element lengths were log-transformed and a Phylogenetic principal components analysis was preformed. In accordance with our predictions, they found flying theropods to have higher rates of evolution in both the fore and hind limb.

It should be noted that our predictions make the assumption that if the integration of traits constrains the ability of a single trait to respond to selection, this could result in a reduced evolutionary rate of that trait. The relationship between evolutionary rate and evolutionary correlation has been overlooked for the most part in the scientific literature, but resent paper by Goswami et al. (2014) discussed and tested this assumption. They hypothesized that if the integration of traits constrains the ability of a single trait to respond to selection, this could result in a reduced evolutionary rate of that trait. This hypothesis was tested using the relative integration within modules in carnivore skulls and the rate of evolution of traits within those modules. They found that strong integration has little influence on rates of evolution.

Trait integration limits the direction in which individual traits can evolve. If selection is acting on a phenotype outside of limited morphospace made available through trait integration, the rate of evolution will be slow or nonexistent. If however selection acts on a phenotype within the available morphospace, evolutionary rates can be extremely fast (Goswami et al. 2014). Therefore the integration of traits, or in this case the integration of forelimb elements and consequential constraint brought on by the biomechanics of flight, and the disintegration of hind-limb elements due to their locomotor functional release by flight, does not necessary affect the rate of trait integration.

Evolutionary Correlation

Non-flying theropods showed a tighter correlation among all three elements of the forelimb than flying theropods, but not significantly tighter. We expected the opposite to be true due to the biomechanics of flight requiring a specific forelimb plan with departures from that plan having adversely affecting the flight function. Evolutionary correlations of forelimb elements seem to reflect the same contradictory pattern as studies of forelimb element proportions (Middleton and Gatesy 2000, Benson and Choiniere 2013). There are at least two possible reasons for this pattern. First, flight requirements do not constrain the evolution of flying theropod limbs. Alternatively, the pattern is reflective of the functional diversity among the forelimbs of flying theropods. The latter seems most plausible. Middleton and Gatesy (2000) found that the humerus never exceeds a length of more than 45 percent the length of the forelimb in birds. If the biomechanical requirements of flight were not enough to constrain the evolution of bird forelimbs, the humerus would be expected to evolve to a length beyond 45 percent of the limb length in some birds. Several Studies (Nudds et al. 2004, Nudds 2007; Simons 2010; Wang et al. 2011), have found that flight styles can be distinguished by characteristic sets of element proportion. Therefore when the evolutionary correlations of forelimb elements of all flying theropods are analyzed together, the result reflects the diversity of function exhibited by birds. We predict that if only birds of one particular flight style were analyzed in isolation, tighter evolutionary correlations would emerge. It was beyond the time limitations of this study to do so, but we have collected flight style information for the taxa studied here and will expand our study accordingly in the future.

The patterns of evolutionary correlations among forelimb elements in both flying and non-flying theropods show the importance of humerus length relative to whole limb length to flight. In fliers, the humerus and radius had the tightest correlation followed by the radius and carpometacarpus, followed by the humerus and carpometacarpus, showing a tightening of correlations among more proximal elements. In non-fliers, the evolutionary correlations involving the most proximal elements were the least tight. The relative length of the humerus plays an important role in the reduction of limb inertia (Middleton and Gatesy 2000) and when flightlessness occurs (both primary and secondary), the humerus seems to become disassociated from the other elements (Middleton and Gatesy 2000). In many cases, the humerus length exceeds the apparent 45 percent of the limb boundary for flight by evolving very little, while the other elements become reduced (Middleton and Gatesy 2000).

Hind limbs have a locomotor function, whether they are those of fliers or non-fliers. Although flying theropods display a variety of hind limb functions (e.g. walking, running, swimming, hopping, perching; Abourachid and Hofling 2012; Pennycuick 1986; Butler 1991), we don't expect any one function to constrain the morphology of limb elements more than any other function. We therefore expect the evolutionary correlations among the hind limb elements to be very similar when comparing flying and non-flying theropods. In contrast, we found that evolutionary correlations among the hind limb elements were tighter in non-flying theropods than in flying theropods. The cause of this result may be the same cause of the forelimb evolutionary correlation result discussed above. Like the forelimbs of flying theropods, the hind limbs of flying theropods can be categorized by many different functions. On the other hand, the hind limbs of non-flying theropods have a more limited repertoire of functions. The looser evolutionary correlations found among hind limb elements of flying theropods may reflect the adaptive divergence to various functions. The ability of any particular hind limb function (e.g., run, hop, swim, dive, etc) might require a specific morphology of hind limb elements, but the origin of flight removed some locomotor constraint from the hind limbs, allowing for the diversification hind limb functions (Gatesy and Middleton 1997).

The patterns of evolutionary correlation among hind limb elements in flying and flightless theropods, opposite to the patterns in the forelimb, show the difference in roles of the femur in flying versus non-bird, flightless theropods. There is evidence that in non-bird theropods (which dominate flightless theropods), the muscle responsible for moving the femur in the actions of running and walking are attached to the femur and the tail (caudofemuralis muscle) resulting a caudofemoral retraction system (Gatesy and Dial 1996). The caudofemoral musculature is reduced or absent in birds due to their highly reduced tails and thus birds use the hamstring muscles to retract the femur (Gatesy 1990; Gatesy 1994; Gatesy and Dial 1996). The absence of a large tail mass in birds also places the center of mass much farther forward in birds than non-bird theropods (Alexander 1983; Manion 1984; Gatesy and Dial 1996). This difference in center of mass results in differing orientations of the femur. We suspect that our results are reflective of the different roles the femur and it's associated muscles play in walk/running and posture to account for the location of the center of mass (Gatesy and Dial 1996).

Conclusion

If biomechanical requirements of flying constrained forelimb element evolution, we expected tighter evolutionary correlations in the forelimb of flying versus non-flying theropods and similar correlations in the hind limbs of flying and non-flying theropods. The results of this study indicated that non-flying theropods have tighter evolutionary correlations than flying theropods in both the fore and hind limbs. Despite the contradictory nature of the results, we believe they are reflective of the diverse functions of the fore and hind limbs of flying theropods.

Several studies have shown that different flight styles require specific forelimb element proportions (Nudds et al. 2004, 2007; Simons 2010; Wang et al. 2011) and that flying theropods show a variety of hind limb functions, made possible by the relaxation of locomotor functional constraint by the evolution of flight (Gatesy and Dial 1996; Gatesy and Middleton 1997; Hunter 1998; Wainwright 2007; Benson and Choiniere 2013). In future studies, we intend to analyze the evolutionary correlations and rates of evolution of theropod limbs for individual functional categories and we expect the results to agree with the predictions made in this study.

CHAPTER 2

CAUSES OF TRAIT COVARIANCE STRUCTURE AND THEIR RELATION TO ONTOGENY IN BIRD LIMBS

Introduction

For decades, Olson and Miller's (1958) thesis that patterns of covariation among morphological traits are caused by functional and developmental influences has been widely recognized (Hallgrimsson et al. 2007). In addition, Cheverud (1982, 1988, 1995, 1996) placed this thesis in the context of quantitative genetics (Hallgrimsson et al. 2007) which led to the hypothesis that patterns of covariation influenced either by function or development in individuals impact genetic covariance structure within populations which impacts the evolution of covariance structure (Cheverud 1996; Marroig and Cheverud 2001; Wagner 1996; Wagner and Attenberg 1996). It is important therefore to distinguish between functional (extrinsic) and historical developmental (intrinsic) factors that influence patterns of covariation to understand the dynamics of covariation structure (and therefore morphological) evolution. It is difficult to do this because a suitable comparison study on trait covariation requires homologous structures with homologous landmarks on a wide variety of organisms of which the phylogenetic relationship is resolved and the homologous structures exhibit various functions. Due in part to this difficulty, few studies to distinguish intrinsic and extrinsic influences have been done (Marroig and Cheverud 2001, 2005; Goswami 2006, 2007; Porto et al. 2009).

Among the first to attempt this, Marroig and Cheverud (2001) used morphological data to construct patterns of covariance among skulls of New World monkey species in order to compare the relationship of covariance structures seen in the monkeys to their phylogenetic and dietary relationships and found that covariance structure was most strongly correlated with diet (e.g. extrinsic influences). Goswami (2006) conducted an extensive study on the skulls of carnivorans and later (Goswami 2007) extended the study to marsupial skulls. Both studies found phylogenetic relationships to be strongly correlated with patterns of covariance at high taxonomic levels, which may suggest different influences on covariance structure are present at different taxonomic levels.

Although comparative morphological integration studies exist for a range of taxa (e.g., Young and Hallgrimsson 2005; Marroig and Cheverud 2001, 2005; Goswami 2006, 2007; Drake and Klingenberg 2010; Bell et al. 2011; Zelditch et al. 2009), studies focused on the determinants of covariation structure have been largely limited to mammal skulls and jaws.

Extrinsic factors may influence patterns of covariation in two distinct ways. First, selection for functional ability can be strong enough to influence the underlying genetics and developmental process, which is then reflected in the phenotypic covariance structure (Zelditch and Carmicheal 1989; Beldade and Brakefield 2003; Ackermann 2005; Hallgrimsson et al. 2009; Zelditch et al. 2009). Second, the performance of a particular function during ontogeny can tailor covariance structure (Badyaev and Foresman 2004; Badyaev et al. 2005). It is possible to rule out the second cause of extrinsic influence by analyzing the covariance structure of embryonic taxa. Since embryonic organisms have not yet performed any locomotor functions, an across-taxa study of covariance structures of embryonic limb elements resulting in a different pattern of similarity of covariance structures than the adult organisms, would reveal that physical use of the limbs was influencing covariation structure. Previous studies have not attempted to rule out performance of a function as the cause of covariance structures of adult organisms.

Here, we attempt to test the relative influences of extrinsic or intrinsic factors upon the adult covariation structure of the limb skeleton of three bird species: domestic chickens (*Gallus*

gallus), domestic ducks (*Anas platyrhynchos*), and brown-headed cowbirds (*Molothrus ater*). We also attempt to rule out performance of a function as the cause of intrinsic factors' influence on covariance structure by analyzing the similarity of influence on covariance structures in the embryonic limbs of these same bird species. Chickens, ducks, and cowbirds are an excellent study system because of their diversity of fore and hind limb functions and phylogenetic relationships (fig. 12), which allow us to make multiple comparisons of covariance structure to function and phylogeny.

We quantified patterns of morphologic covariance structure using variance/covariance matrices of linear measurements of the fore and hind limb skeletal elements. The following five evolutionary hypotheses were tested:

1) If patterns of covariance are determined predominantly by intrinsic factors, but these factors evolve over time (but not in relation to function), closely related species will have more similar matrices than when compared with distantly related species, meaning the similarity of variance/covariance matrices among species is a function of phylogenetic "distance."

2) If patterns of covariance are determined predominantly by function (i.e., natural selection for a function), functionally similar taxa will be more similar than would be expected given their phylogeny.

3) If patterns of covariance are determined by a complex relationship between intrinsic and extrinsic factors, the similarity of variance/covariance matrices will show no pattern with respect to phylogeny or function.

4) If extrinsic influence dictates ontogenetic appearance of patterns of trait covariance and this is done with the application of function during ontogeny, patterns of covariance seen in the adult birds will appear later in ontogeny.

5) If intrinsic influence dictates ontogenetic appearance of patterns of trait covariance and selection for functional ability has influenced the developmental process, patterns of covariance seen in the adult birds will appear early in ontogeny.

If intrinsic factors are the main influence, we expect adult ducks and chickens to have more similar covariance structures than adult ducks and cowbirds for both the fore and hind limb. This pattern of similarity reflects the phylogenetic relationship of these birds because ducks are more phylogenetically distant to cowbirds than to chickens (Hackett et al. 2008). We would also expect the embryos of these species to express the same pattern of similarity because intrinsic factors would be the main influence throughout ontogeny if they are present in adulthood.

If extrinsic factors are the main influence on covariance structure, we expect the forelimb covariance structures would be more similar between adult duck and cowbird than between adult duck and chicken. We expect this because ducks and cowbirds exhibit much stronger flight capability then chickens. Chickens display rapid take-off and short flights, ducks display sustained, high-frequency flapping flight, and cowbirds display standard, sustained, horizontal flight (Ponton et al. 2007). Feathers comprise much of the aerodynamic surface of bird wings, however several studies have shown that skeletal measurements strongly discriminate birds of differing flight styles and behaviors (Nudds and Dyke 2010; Nudds 2007; Habib and Ruff 2008; Simons 2010). If extrinsic factors are the main influence on covariance structure, we expect one of two possible patterns of similarity among the hind limbs of the three adult bird species. Chickens and ducks are hatched on the ground and their hind limbs are required to function quickly after emerging from the egg (i.e., precocial development), while cowbirds reside in nests off the ground and have hind limbs with little to no functional requirement immediately after hatching (i.e., altricial development) (Starck and Ricklefs 1998). Because of the similar precocial development of chickens and ducks, one could expect chickens and ducks to have more similar hind limb covariance structures than ducks and cowbirds or chickens and cowbirds. However, as adults, ducks and chickens are able to walk, although when speed is required chickens have the ability to run while ducks are less able to do so. Cowbirds are able to walk and run (Laskey 1950). All three species are able to perch, however ducks do this very awkwardly and not often. Chickens are less awkward at perching and cowbirds spend much of their lives in this position (Bolen and Rylander 1974; Rodenburg et al. 2005, Brugesch et al. 2011). Because of the similar adult hind limb functional ability of chickens and cowbirds, one could expect chickens and cowbirds to have more similar hind limb covariance structures than chickens and ducks or ducks and cowbirds.

If extrinsic factors mainly influence covariance structure and the developmental process previous to hatching was affected by selection for functional ability, we expect that the pattern of similarities within embryonic fore and hind limbs would reflect those of adult birds in which extrinsic factors are also the main influence.

If extrinsic factors are the main influence, and covariance structure is tailored by the performance of a function, or if the developmental process was affected by selection post-hatching, we expect that pattern of similarities in embryonic fore and hind limbs to reflect the phylogenetic relationships of the birds. We expect this because no functional requirements should be present in the limbs of the unhatched embryo.

Methods

Samples

For this study we obtained and skeletonized 27 adult New Hampshire Brown chickens (*Gallus gallus*) from the University of Illinois Urbana-Champaign (UIUC) Poultry Research Facility, 50 Pekin ducks (*Anas platyrhynchos*) from Maple Leaf Farms, and 67 brown-headed cowbirds (*Molothrus ater*) from the UIUC Department of Natural Resources and Environmental Sciences. The tarsometatarsus was unavailable for ducks and was therefore left out of this study. We obtained embryos of the same species. Embryonic chickens (27 in total) were obtained from eggs received from the UIUC Poultry Research Facility. Embryonic ducks (29 in total) were obtained in the same way from Metzer Farms Duck and Goose Hatchery. Embryonic cowbirds (13 in total) were obtained from collections in the UIUC Department of Natural Resources and Environmental Sciences. All embryos were staged to HH 24 (Hamburger and Hamilton 1951). This stage was selected because the embryos exhibited the landmarks chosen for the adults and hatching had not yet occurred for any of the species. The embryos were cleared and bone and cartilage were stained using the method described in Yamazaki et al. (2011). The limb elements used represented the stylopod (i.e., humerus and femur in the fore and hind limbs, respectively), zuegopod (i.e., radius and tibiotarsus), and autopod (i.e., carpometacarpus and tarsometatarsus) of both the fore and hind limbs.

Landmarks and Linear Measurements

We chose previously used two-dimensional landmarks (fig. 13) (Von Den Driesch 1976). We took digital photographs of adult limb elements and recorded landmarks using imageJ (Abramoff et al. 2004). The stained embryonic limb elements were then landmarked using a reflex microscope. We recorded coordinates for nine landmarks on all humeri, seven on all radii, ten on all carpometacari, eight on all femora, eleven on all tibotarsi, and nine on all tarsometatarsi. We collected landmarks for each bone three times on all specimens to quantify measurement error. We used Procrustes Superimposition of the landmarks of each limb element of each bird species to identify any peculiar landmarks. If the peculiarity was due to measurement error or a morphological deformity, we removed the specimen from the analysis. Then, we used the mean of the three replicate landmark acquisitions as the landmarks for individual specimens. From these landmarks, we generated linear measurements of the lengths and distal widths of each element. These linear measurements can be seen in Appendix E. We calculated the measurement error of individual linear measurements by estimating the variance components (percent of variation within individuals and the percent of variation among individuals) in a single classification ANOVA with unequal sample sizes, as described in Sokal and Rohlf (1981).

Variance/Covariance Matrices

Length and width measurements of each limb element were calculated using the mean coordinates of each landmark. Variance/covariance matrices were then produced for each adult and embryonic bird species using the length and width measurements. Variance/covariance matrices were produced separately for fore and hind limb measurements. We compared the structures of these matrices separately in the hind and forelimb among species and ontogenetic stages using random skewers (Lande 1979; Manly 1991; Cheverud 1996; Cheverud and Marroig 2007). Specifically, we sampled each matrix 10,000 times, and multiplied the same set of 10,000 random skewers (drawn from a normal distribution and standardized to unit length) to each set of resampled matrices resulting in response vectors of each covariance matrix as described in

Cheverud (1996). We quantified matrix similarity as the angle between response vectors (a.k.a vector correlations) for all possible pairs of adult species and all possible pairs of embryonic species. We also quantified matrix similarity between all possible pairs of adult and embryonic forms of the same species. The vector correlations were then put on a 0-1 scale by taking the cosine of all angles. Normal distributions of the cosine of all vector correlations were calculated and p-value of these distributions were calculated using a z-test. Matrix repeatability was calculated for all variance/covariance matrices as the average vector correlation between response vectors of the resampled matrices and the raw matrices (Marroig and Cheverud 2001).

Results

Measurement Error and Matrix Repeatability

The proportion of variation among groups for all measurements of limb elements of all bird species (both embryonic and adult) ranged between 58.4 and 99.9 percent (Table 5). These proportions indicate that measurement error was low for all measurements and therefore does not affect the results of this study. Matrix repeatability for adult forelimbs ranged from 0.923 to 0.970. Matrix repeatability for embryonic forelimbs range from 0.890 to 0.916. Matrix repeatability for adult hind limbs ranged from 0.934 to 0.972. Matrix repeatability for embryonic hind limbs range from 0.864 to 0.918. (Table 6). Given that measurement error was calculated to be relatively high, the matrix repeatabilities suggest that any variation found among matrices is due to actual biological variation or differences in the way in which specimens were obtained and/or variation in element orientation between measurements of different specimens. Variation among matrices could also be due to small sample size. The sample size of cowbird embryos is fairly small (13 individuals). All embryos could have been affected by slight variations in humidity during development and all embryos were landmarked while coated in glycerin to prevent desiccation, which would allow for variations in orientation among the landmarks of different specimens.

Variance/Covariance Matrices

Distributions of all similarities across bird pairs were found not to be significantly different in all similarity pairs. The p-values for all tests, the median angles between response vectors, and the mean difference between response vectors for all possible comparisons can be found on Table 7. Distributions of the angles between response vectors of duck and chicken covariance matrices as well as those of duck and cowbird, and cowbird and chicken for both adult and embryonic birds can be seen in figures 14-17. Distributions of the angles between response vectors of adult and embryonic duck covariance matrices as well as those of adult and embryonic chicken, and adult and embryonic cowbird for both the fore and hind limb can be seen in figures 18 and 19.

It must be noted that both adult duck and adult cowbird specimens consisted of both sexes and the sex of individual birds was unknown, making testing for sexual dimorphism within the covariance structures of the limb elements impossible.

Discussion

The low matrix repeatabilities of the embryonic specimens and the real possibility that variations during incubation, small sample size, and variation in orientation among specimens during landmarking indicated that the results calculated for similarity of covariance structure among embryonic species are inconclusive. In the same respect, results for comparisons among similarity between covariance structures of all adult and embryonic forms of each species are also inconclusive. In future, more specimens must be analyzed to rule out small sample size as a cause of high matrix repeatability. Also all embryonic specimens should be incubated simultaneously in the same incubator to reduce variations in humidity. Lastly, all embryonic limb elements should be photographed and landmarked using imageJ software to ensure identical orientations of all elements.

If future studies are able to increase matrix repeatability for embryonic variance/covariance matrices, the covariance structure of more ontogenetic stages must be analyzed. This analysis would allow the investigation of when, during ontogeny, functional influence becomes the main influence to better understand if performance of a function influences patterns of covariation resulting in the adult covariation structure which would be variable based on environment, not genetics (Badyaev and Foresman 2004; Badyaev et al. 2005). Shifts in the timing of developmental processes are an important mode of evolutionary change (McNamara and McKinney 2005; Schlosser 2005). The patterns of covariation of many more ontogenetic stages must be studied to understand exactly when during ontogeny shifts in covariance structure occur compared to other taxa and the causes of those shifts, which in turn will lead to a better understanding of how covariance structures relate to morphologic evolution.

Few studies have looked at changes in covariance structures over ontogeny compared across related taxa (Coquerelle et al. 2013; Kolarov et al. 2011; Wilson 2013; Christensen 2012; Goswami et al. 2012; Ackermann 2005). All studies have analyzed the covariance structure at several ontogenetic stages of each species to find the patterns and magnitudes of integration and compare those to the patterns and magnitudes of integration seen among the adult forms. A difference in magnitude between adult and embryonic forms among taxa may indicate differences in early developmental plasticity and differences in timing of changes in patterns of integration between adult and embryonic forms among taxa may provide evidence for how early selection for function dictates integration by affecting the developmental process or underlying genetics.

If the adult covariance structure is based on performance of a function over the life of the organism, then the genetic and developmental processes of the limbs may still be correlated with phylogenetic relatedness, despite the covariance structure being associated with functional influence. If instead the adult covariance structure is based on a changed developmental process due to selection for a function, it may be suggested that chickens (at least in the case of forelimbs) diverged from the covariance structure of duck and cowbird, which are strong fliers and should possess more ancestral covariance structures relating to strong flight ability since all birds descend from ancestors with strong flight ability (Middleton and Gatesy 2000).

The covariance structures of adult duck, chicken, and cowbird forelimbs were not significantly different from each other. The covariance structures of adult hind limbs showed the same relationship. These results do not correspond to any of our predictions. There are two possible explanations for this. First, our sample sizes may not be large enough to reflect the real-world relationship among similarities of covariance structures of the three bird species used in this study. However, our sample sizes seem to reflect numbers that are acceptable in across-taxon studies. Second, the species analyzed in this study may posses shared developmental processes (Klingenberg et al. 2003; Marroig et al. 2004; Hallgrimsson et al. 2007) due to genes or developmental events with pleiotropic effects (Mitteroecker and Brookstein 2008; Singh et al. 2012) resulting in similar covariance structures in the fore and hind limb.

Several studies have found this result at different taxonomic levels of mammals, particularly primates (Porto et al. 2009; Singh et al. 2012; de Oliveira et al. 2009; Polanski 2011;

Willmore et al. 2009; Makedonska et al. 2012). Most of these studies hypothesized that despite similar patterns of covariance, different phenotypes were able to evolve due to differences in magnitude of covariance structure (Porto et al. 2009; Singh et al. 2012; de Oliveira et al. 2009; Makedonska et al. 2012). Another possibility is that over-all covariance structure is similar between taxa, but that localized covariance structure (within modules) is dissimilar (Willmore et al. 2009). To confirm if changes in magnitude affect the disparity of phenotypes, future studies on these species need to include an analysis of covariance structure magnitude. In either case, our results indicate that the developmental patterns resulting in common patterns of covariance are conserved across Neognaths.

Hind limb results may also be affected by the absence of the tarsometatarsus from the study. The tarsometatarsus varies greatly in length in birds (13 – 45 percent of the total limb length) and seems to increase in length relative to total limb length with increasing cursoriality (Gatesy and Middleton 1997). The tarsometatarsus therefore could contribute quite a bit to patterns of covariance similarity.

Conclusion

This study attempted to test whether intrinsic or extrinsic influences affected the patterns of covariance structure of the fore and hind limbs are chickens, ducks and cowbirds and the implications of the ontogenetic timing (pre or post hatching) of those influences. We found that the covariance structures among adult forelimbs and hind limbs, across taxa, were statistically indistinguishable from one another. Because adult sample sizes seem to be sufficient, this result indicates that the developmental process of the fore and hind limbs is conserved across chickens, ducks, and cowbirds. The measureable difference in limb morphology among these birds could be due to differences in magnitude of covariance structure and has been hypothesized in skulls, mandibles and limbs of various groups of mammals (Porto et al. 2009; de Oliveira et al. 2009; Singh et al. 2012; Makedonska et al. 2012). It may also be due to differences among patterns of covariance within individual modules that are integrated with other modules to form the over-all covariance structure of the limb, similar to what has been found between the covariance structures of Baboon and mouse mandibles (Willmore et al. 2009). Future studies must investigate magnitude differences of the covariance structures in the bird species analyzed in this study to determine if the magnitude discriminates phenotypic morphological differences.

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FIGURES

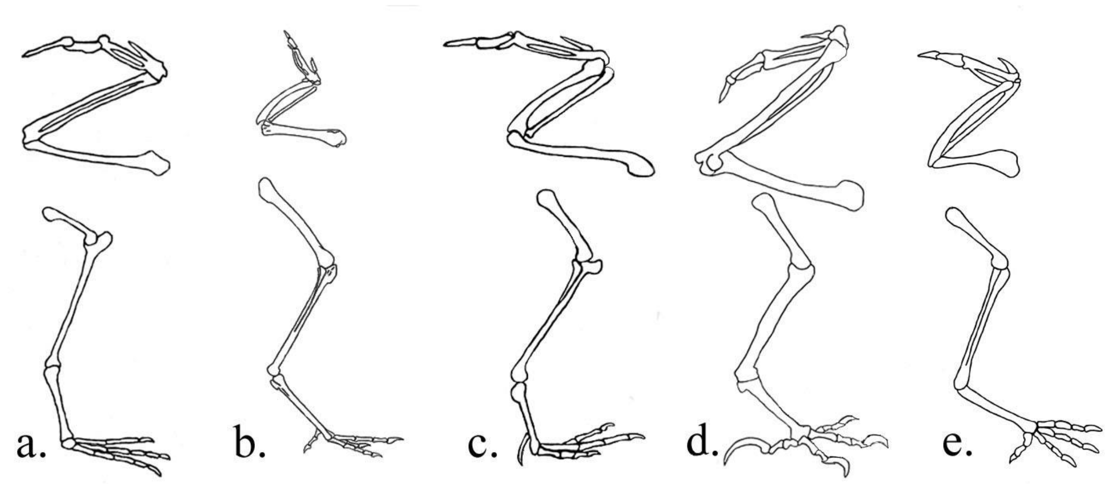

Figure 1. a. petrel limbs, associated with gliding and soaring flight; b. chicken limbs, associated with rapid take-off and short flights; c. duck limbs, associated with high-frequency flapping flight; d. eagle limbs, associated with undulating flight characterized by a phase of powered flight followed by a phase of gliding flight; e. robin limbs, associated with standard, sustained, horizontal flight

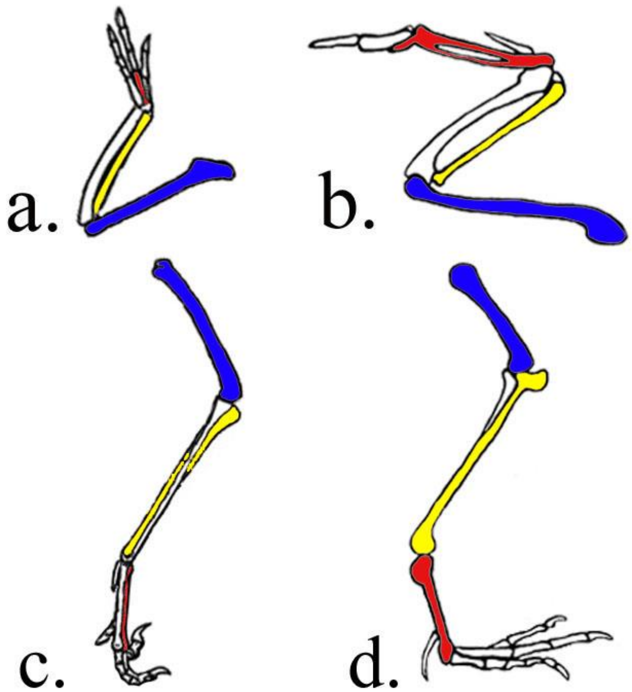

Figure 2. a. non-avian theropod forelimb; b. avian theropod forelimb; c. non-avian theropod hind limb; d. avian theropod hind limb; Forelimb: blue = humerus, yellow = radius, red = metacarpal II or carpometacarpus. Hind limb: blue = femur, yellow = tibia or tibiotarsus, red = metatarsal III or tarsometatarsal

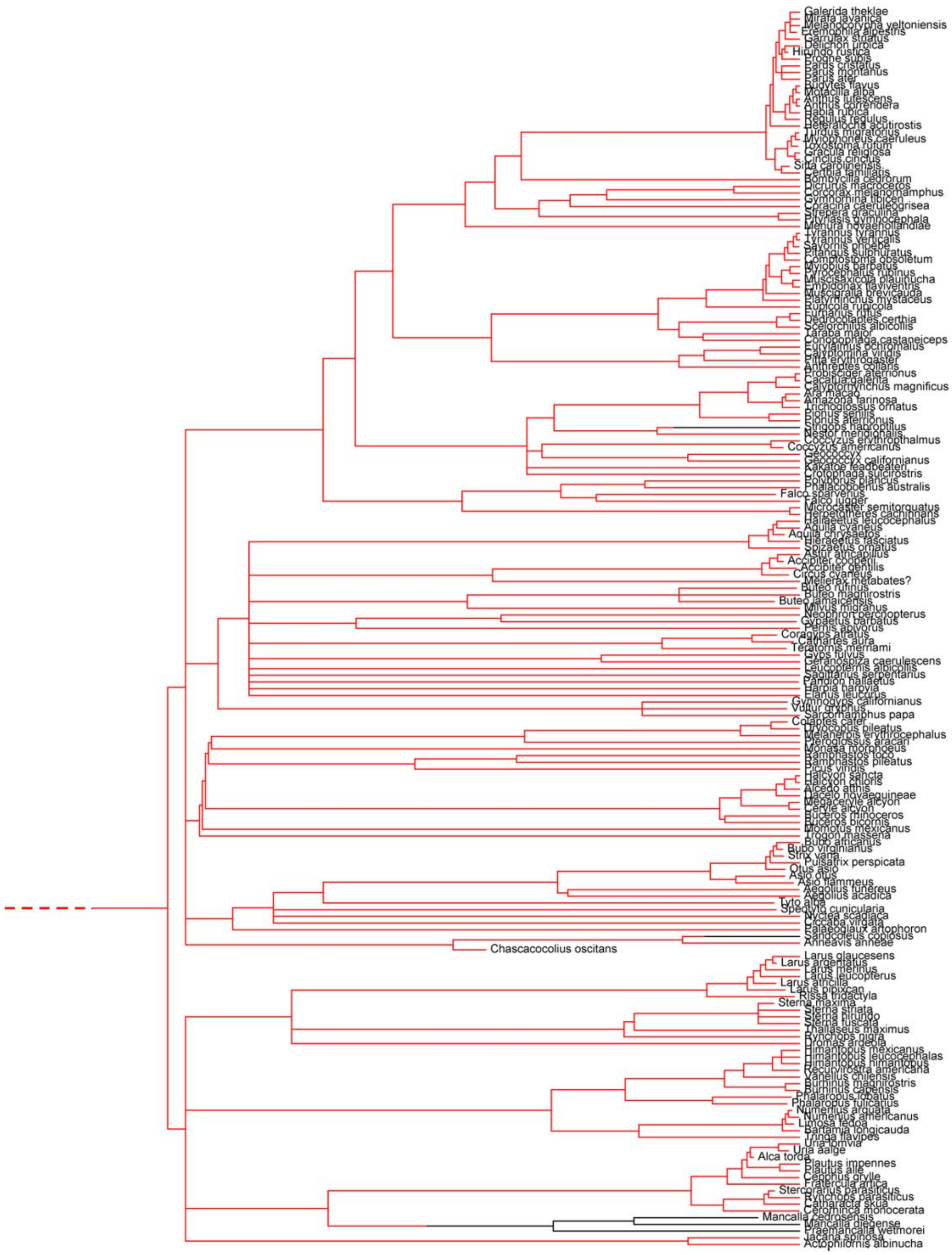

Figure 3. Composite phylogenetic tree constructed using Mesquite software representing the evolutionary relationships among the 654 avian and non-avian theropod taxa; Flying lineages are colored red, non-flying lineages are colored black

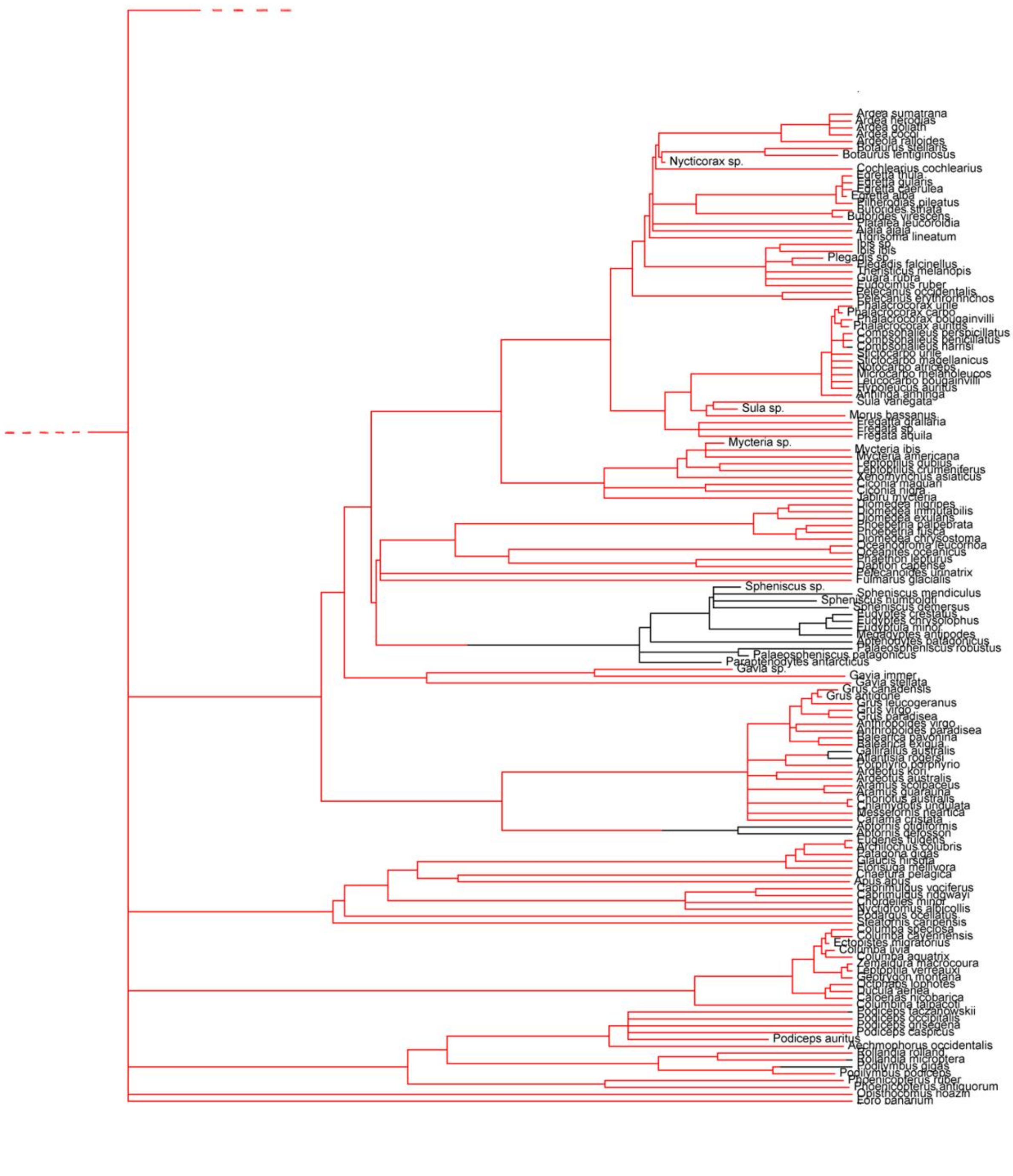

Figure 3 (cont.)

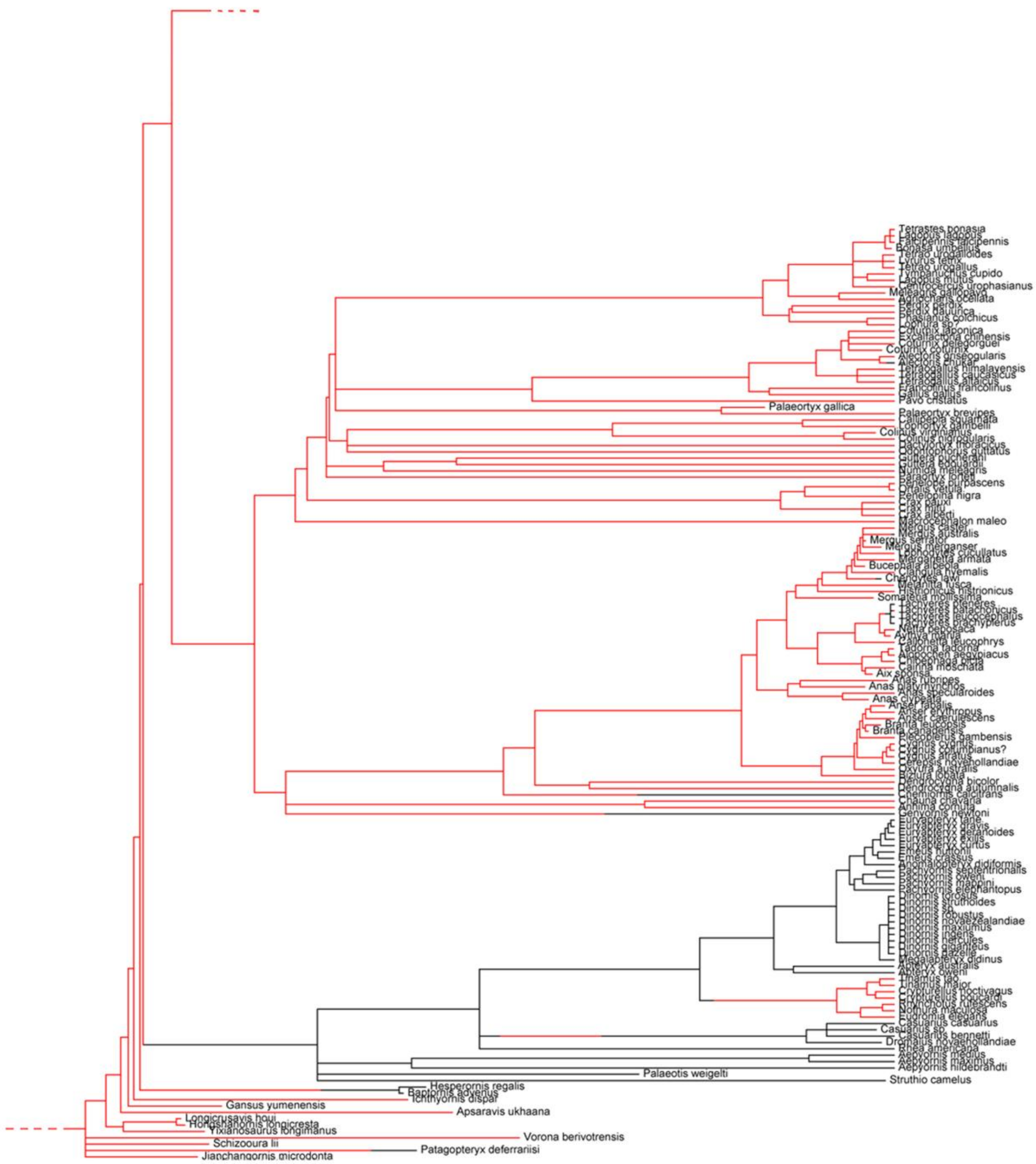

Figure 3 (cont.)

Figure 3 (cont.)

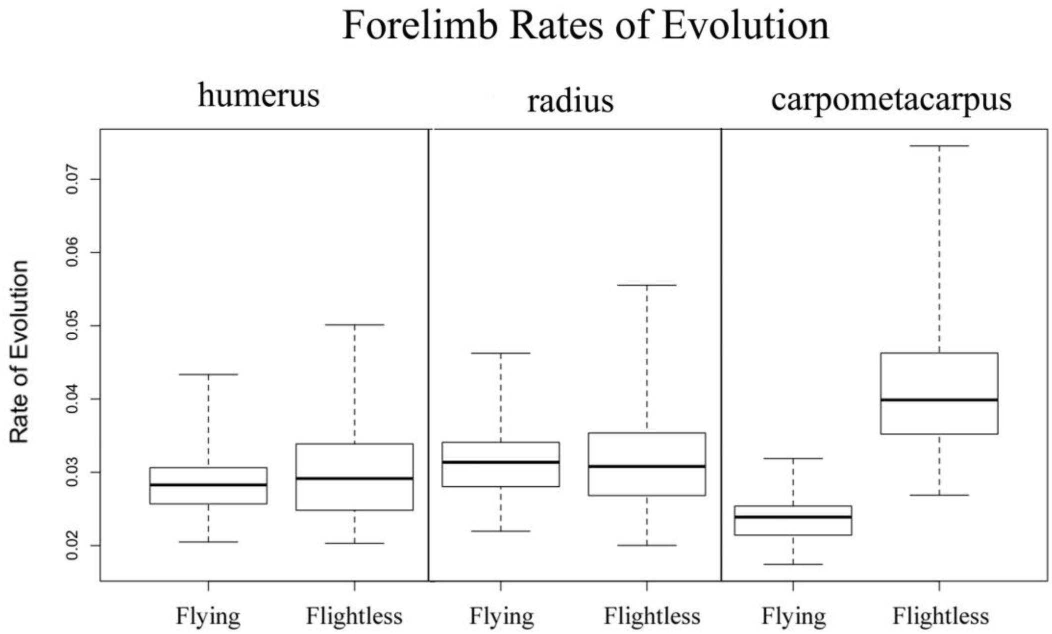

Figure 4. Box-plots of the distributions of rates of evolution for elements of the forelimb in flying and flightless theropods

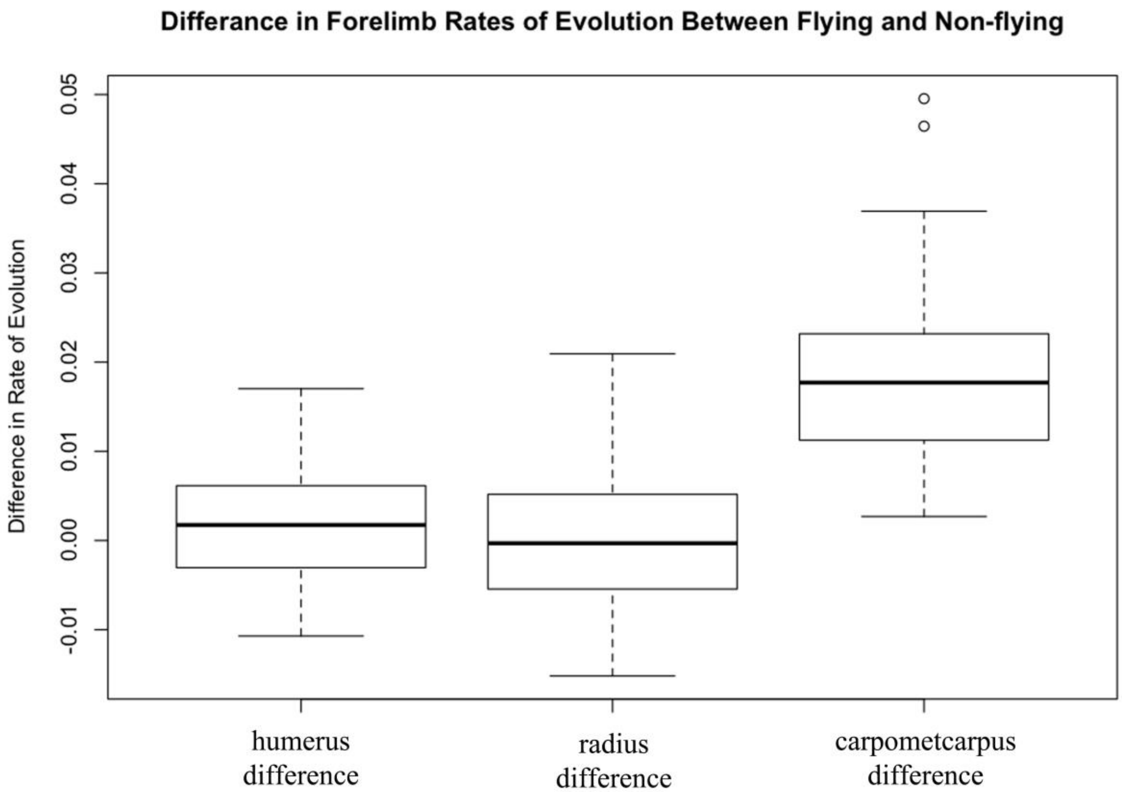

Figure 5. Box-plots of the distributions of differences between flying and flightless theropods for each forelimb element

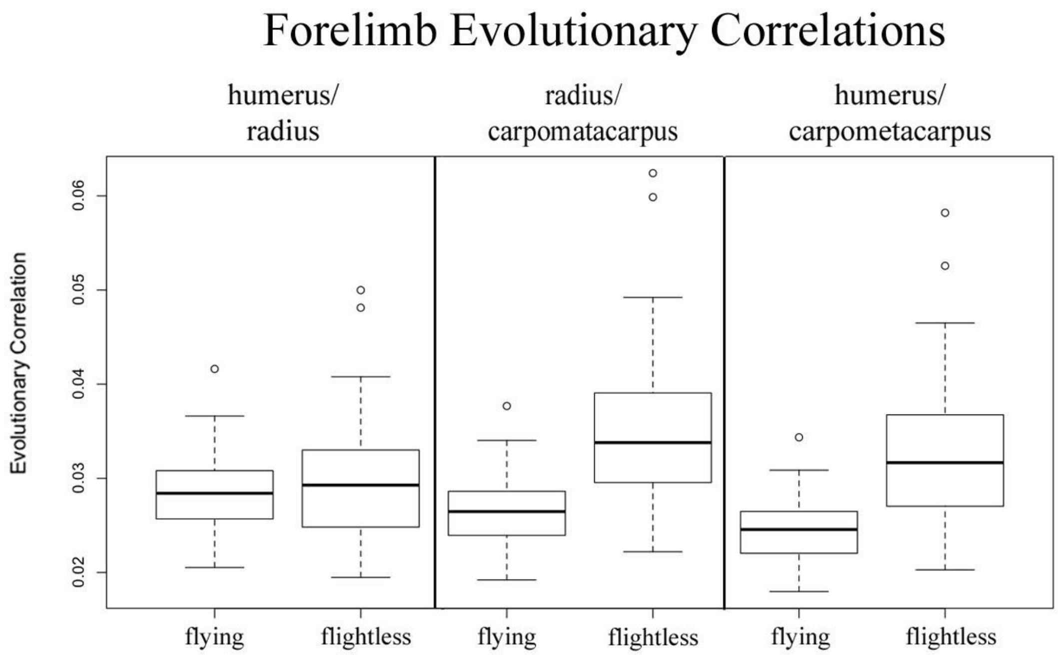

Figure 6. Box-plots of the distributions of evolutionary correlations for each pair of forelimb elements in flying and flightless theropods

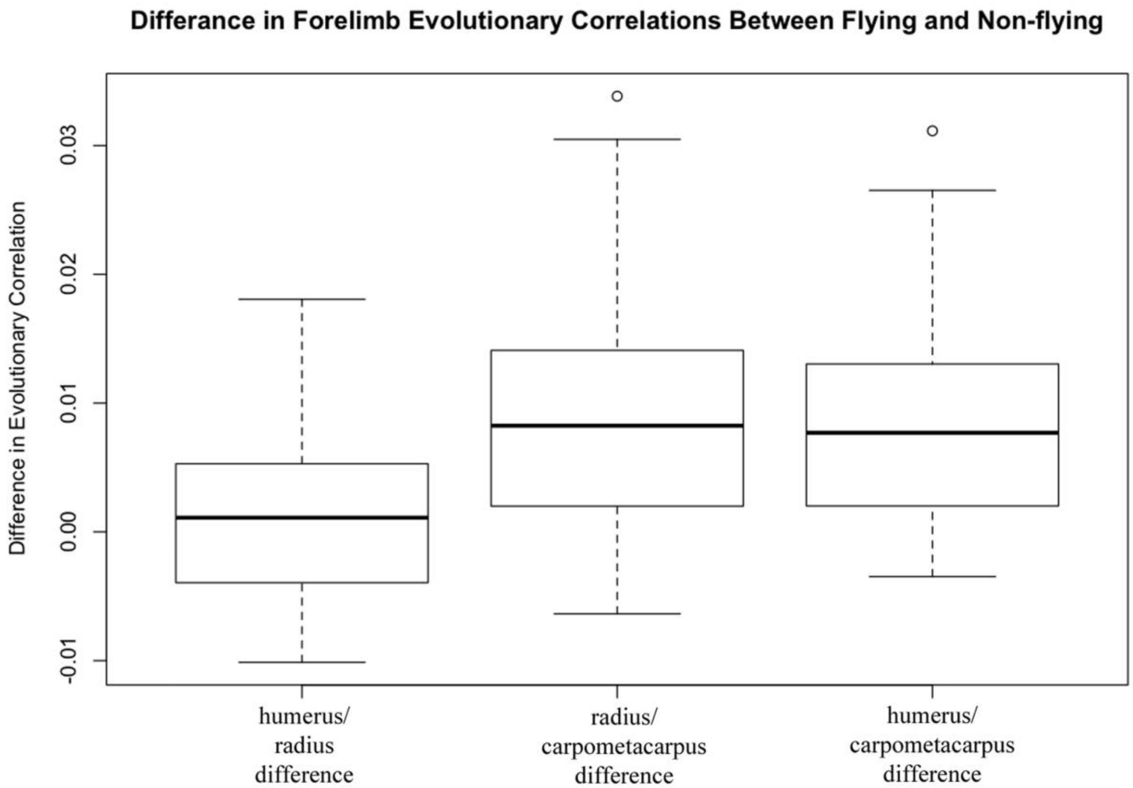

Figure 7. Box-plots of the distributions of differences between flying and flightless theropods for each forelimb element pair

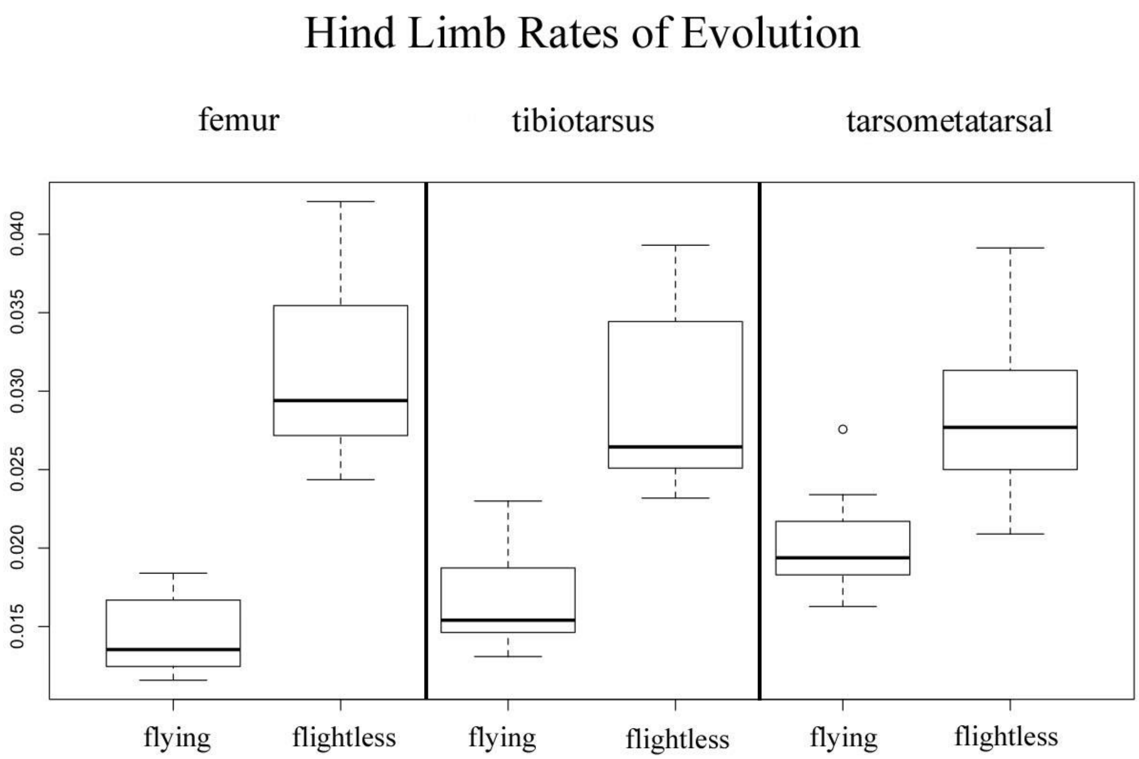

Figure 8. Box-plots of the distributions of rates of evolution for elements of the hind limb in flying and flightless theropods

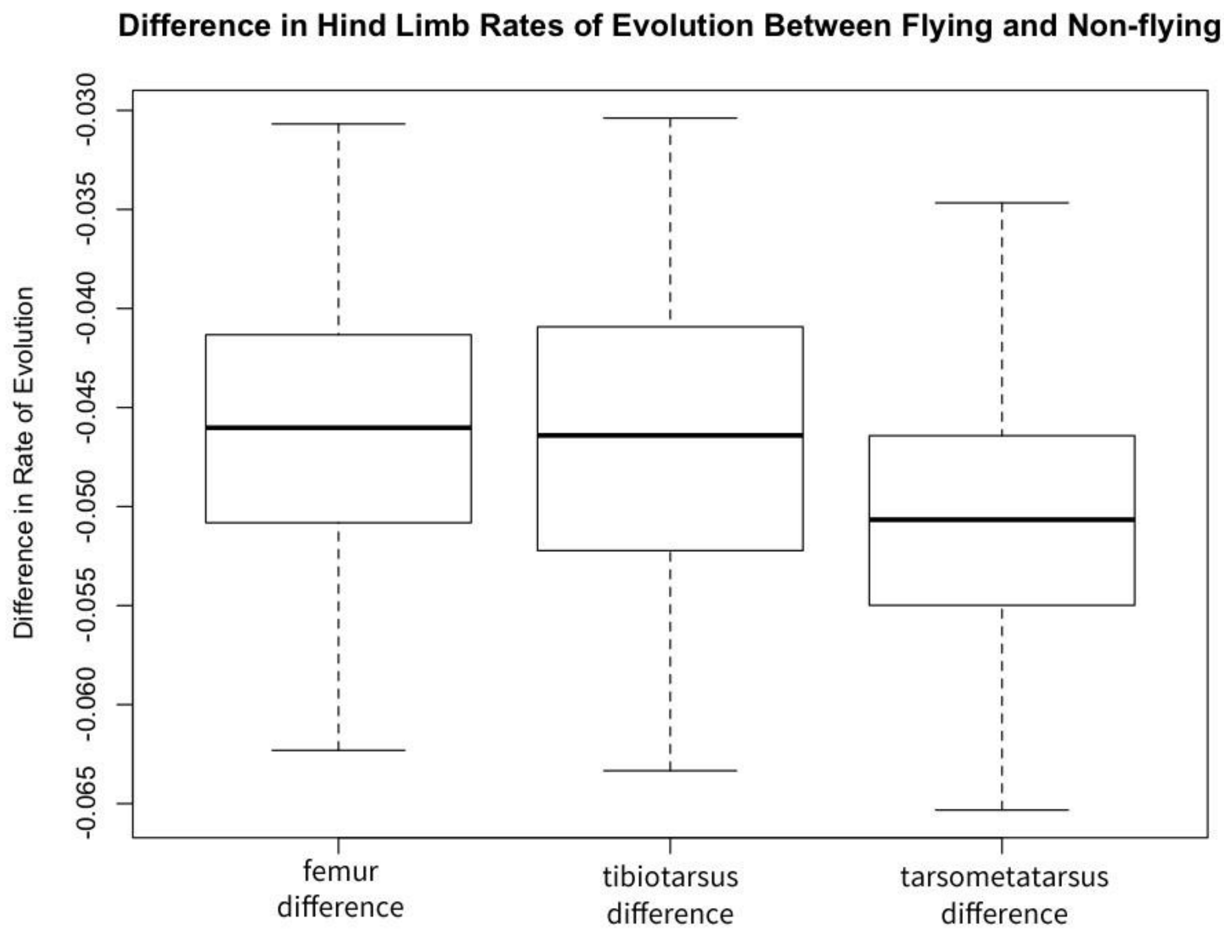

Figure 9. Box-plots of the distributions of differences between flying and flightless theropods for each hind limb element

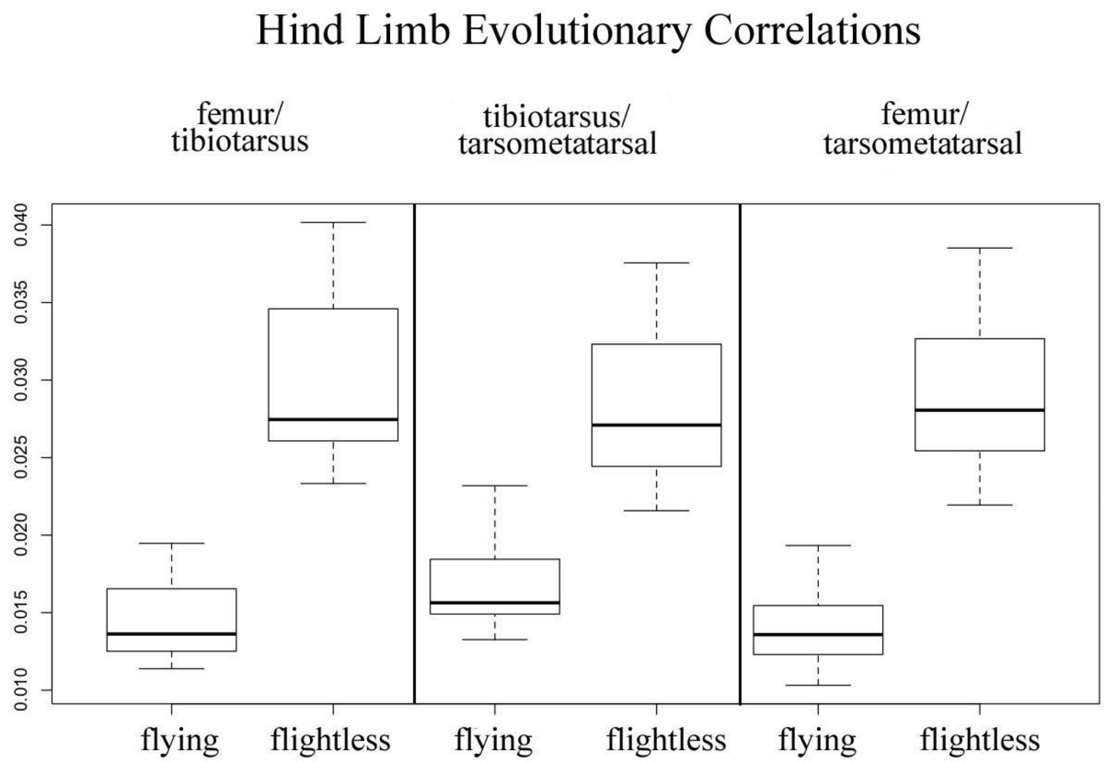

Figure 10. Box-plots of the distributions of evolutionary correlations for each pair of hind limb elements in flying and flightless theropods

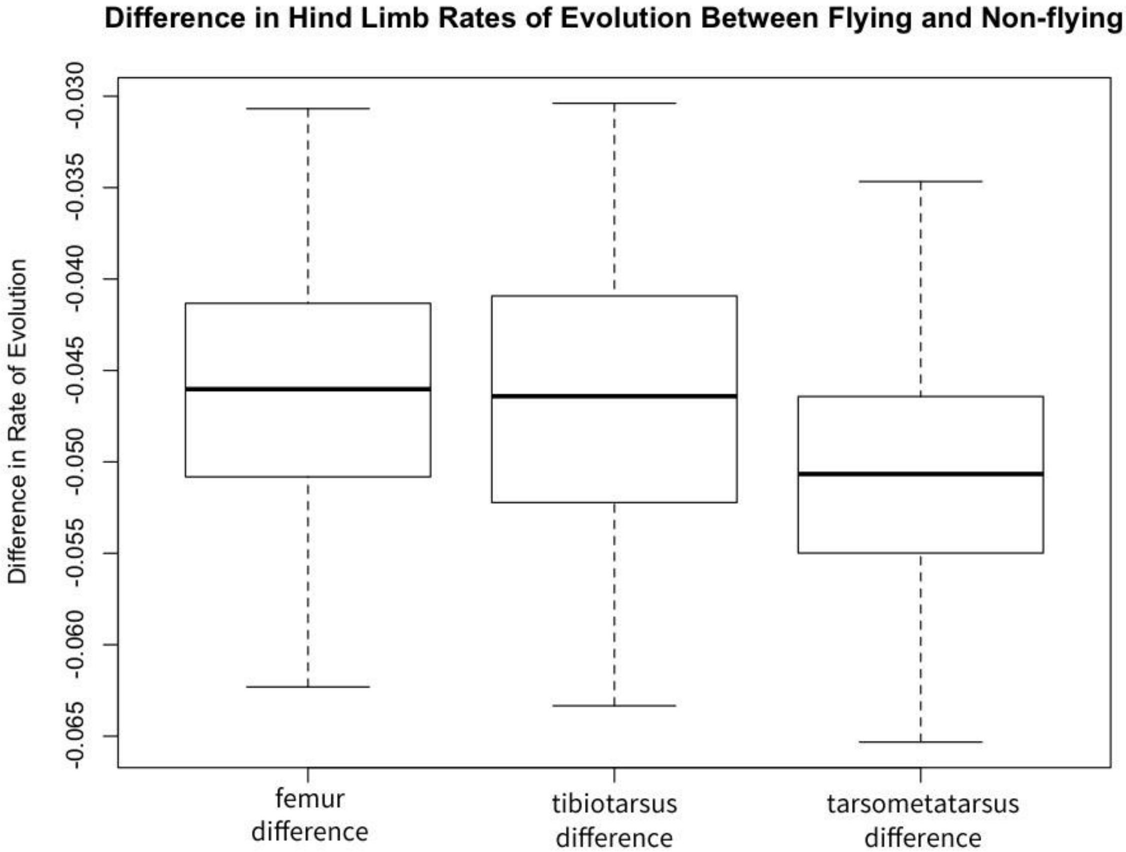

Figure 11. Box-plots of the distributions of differences between flying and flightless theropods for each hind limb element pair

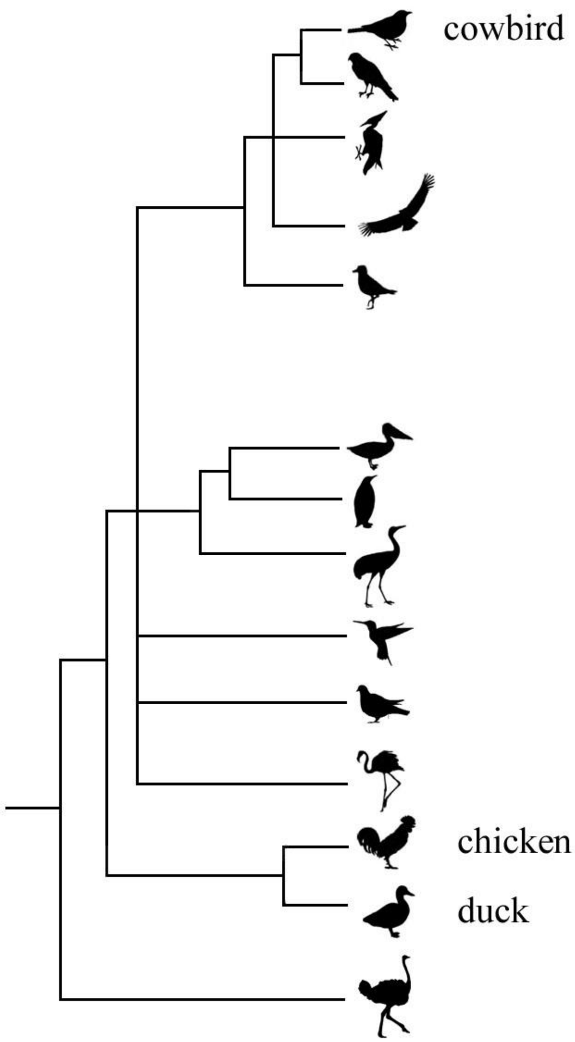

Figure 12. Simple phylogeny of birds based on Hackett 2008

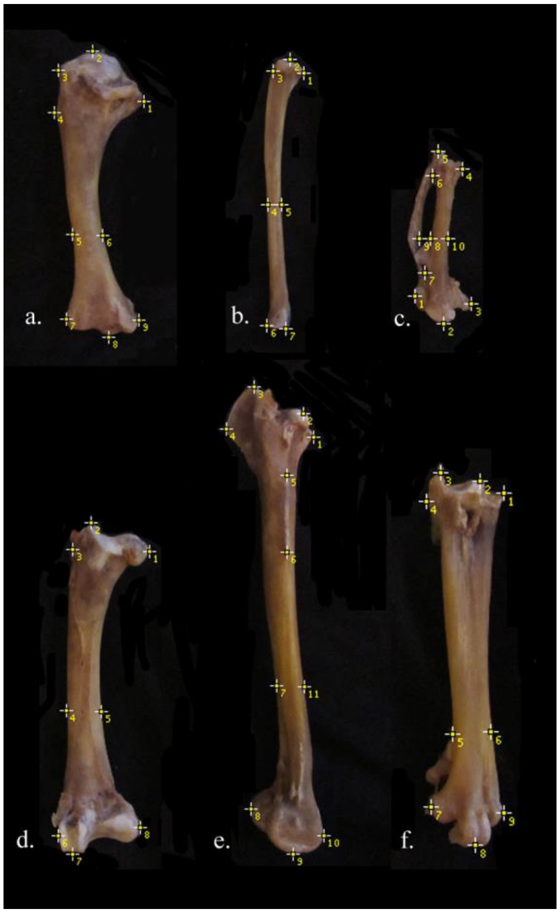

Figure 13. Landmarks for the humerus (a.), radius (b.), carpometacarpus (c.), femur (d.), tibiotarsus (e.), tarsometatarsus (f.)

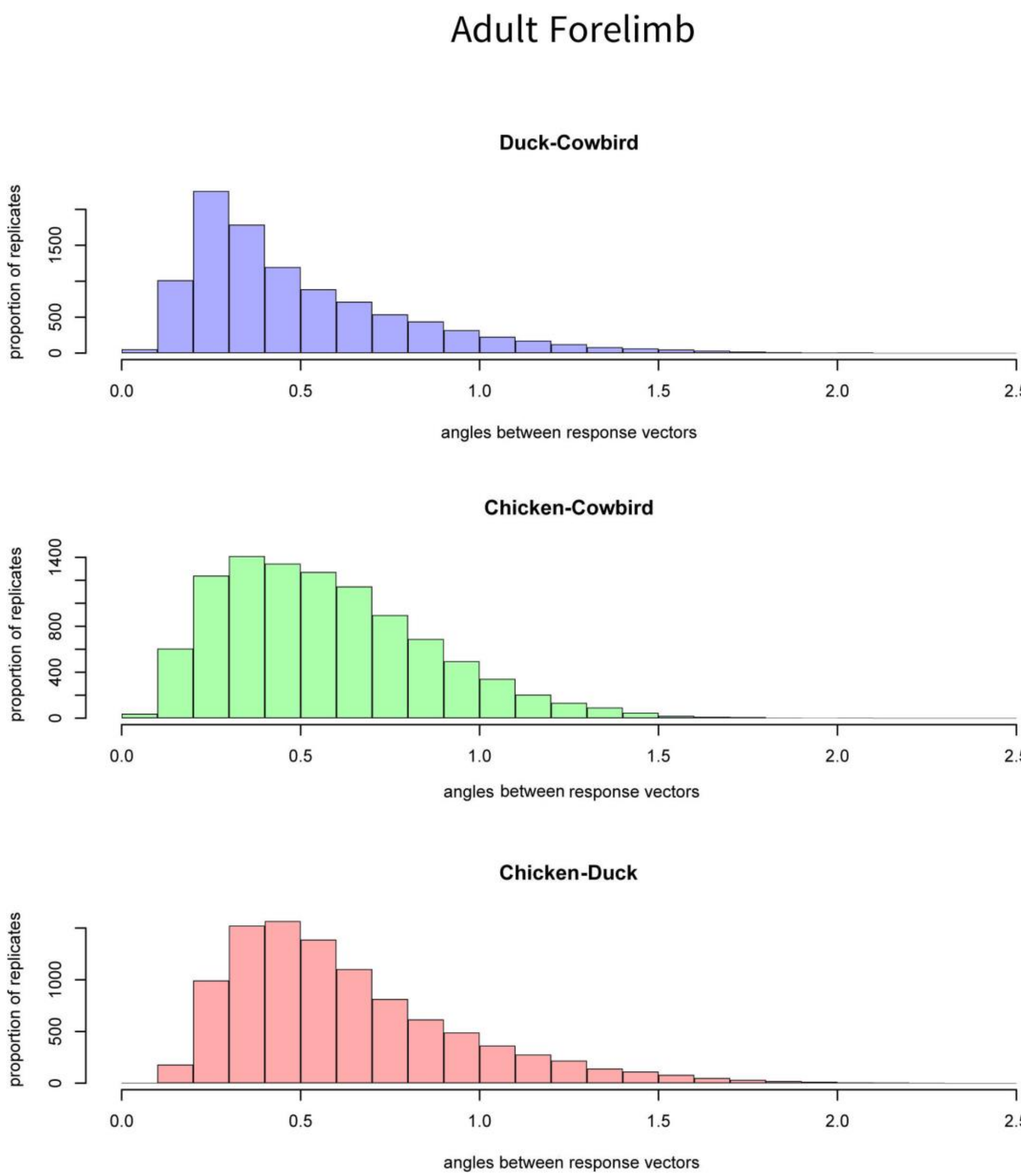

Figure 14. The distributions of angles between the response vectors of adult duck and chicken forelimb covariance matrices as well as those of adult duck/adult cowbird and adult chicken/adult cowbird

Adult Hind Limb

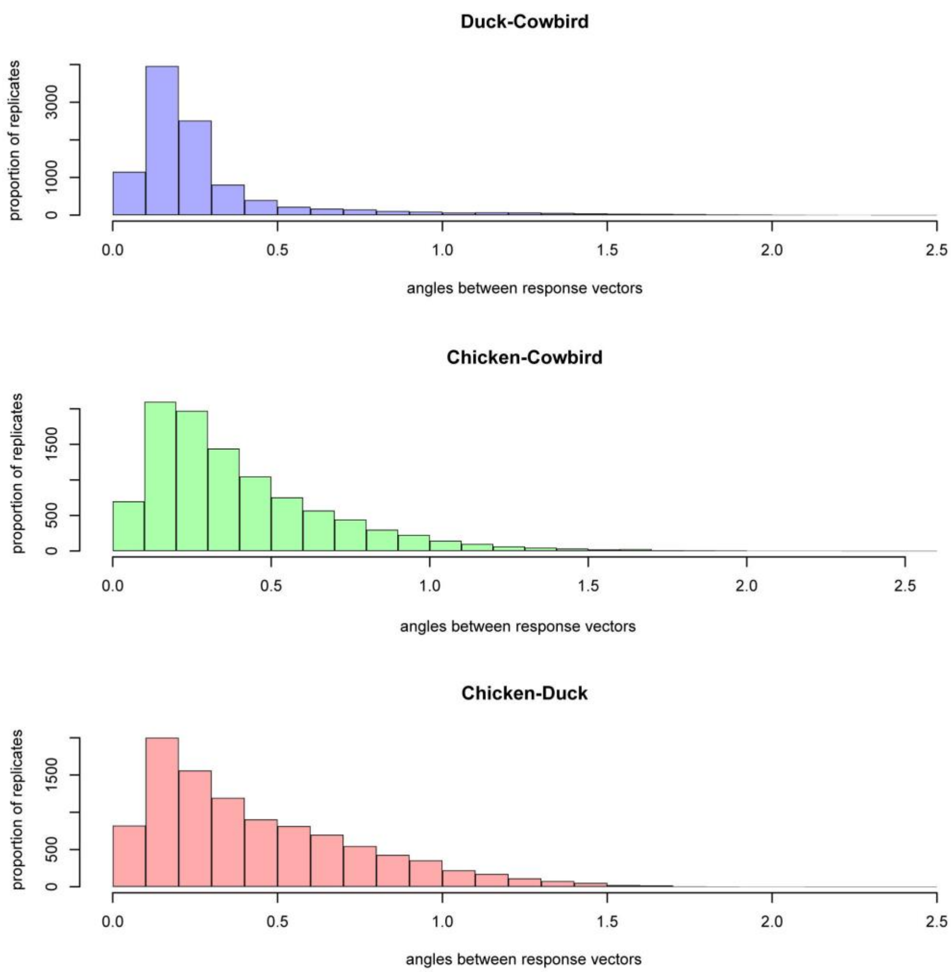

Figure 15. The distributions of angles between the response vectors of adult duck and chicken hind limb covariance matrices as well as those of adult duck/adult cowbird and adult chicken/adult cowbird

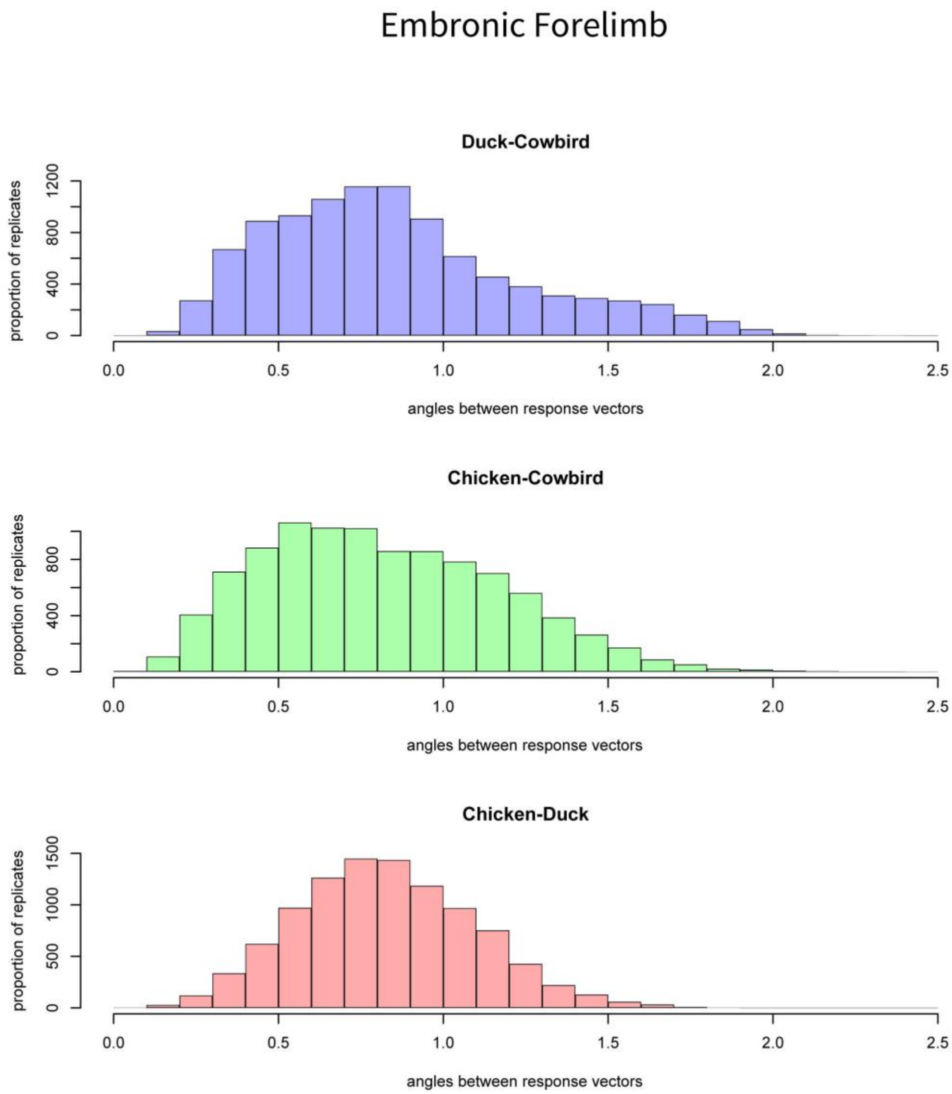

Figure 16. The distributions of angles between the response vectors of embryonic duck and chicken forelimb covariance matrices as well as those of embryonic duck/cowbird and embryonic chicken/cowbird

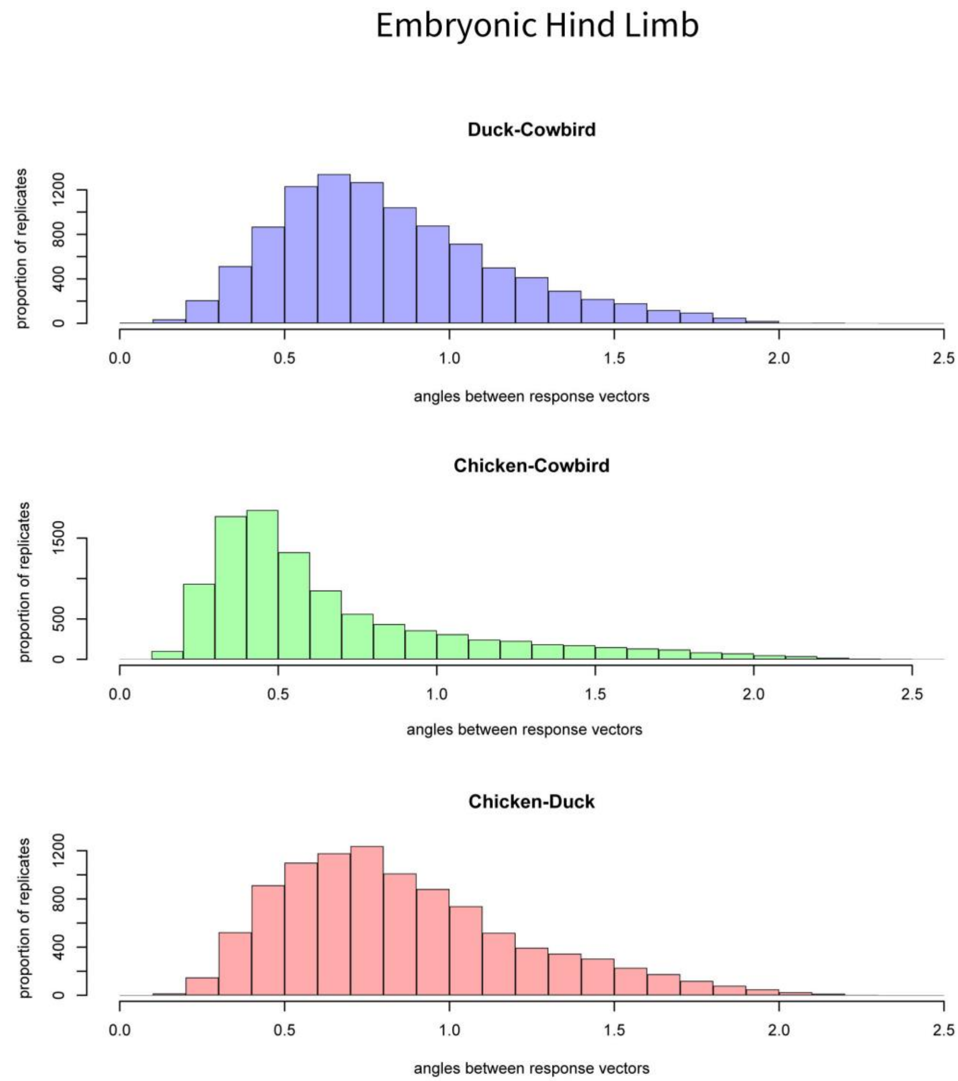

Figure 17. The distributions of angles between the response vectors of embryonic duck and chicken hind limb covariance matrices as well as those of embryonic duck/cowbird and embryonic chicken/cowbird

Embryonic-Adult Forelimb

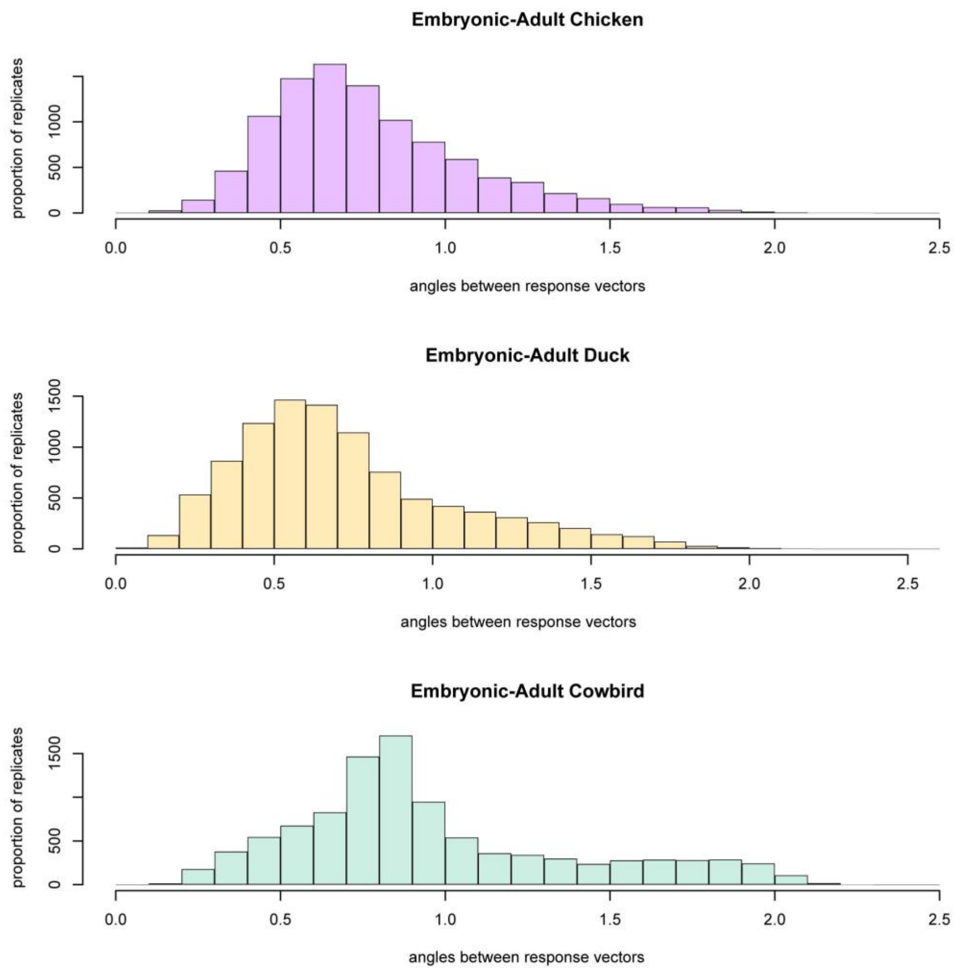

Figure 18. The distributions of angles between the response vectors of embryonic and adult chicken forelimb covariance matrices as well as those of embryonic/adult cowbird and embryonic/adult cowbird

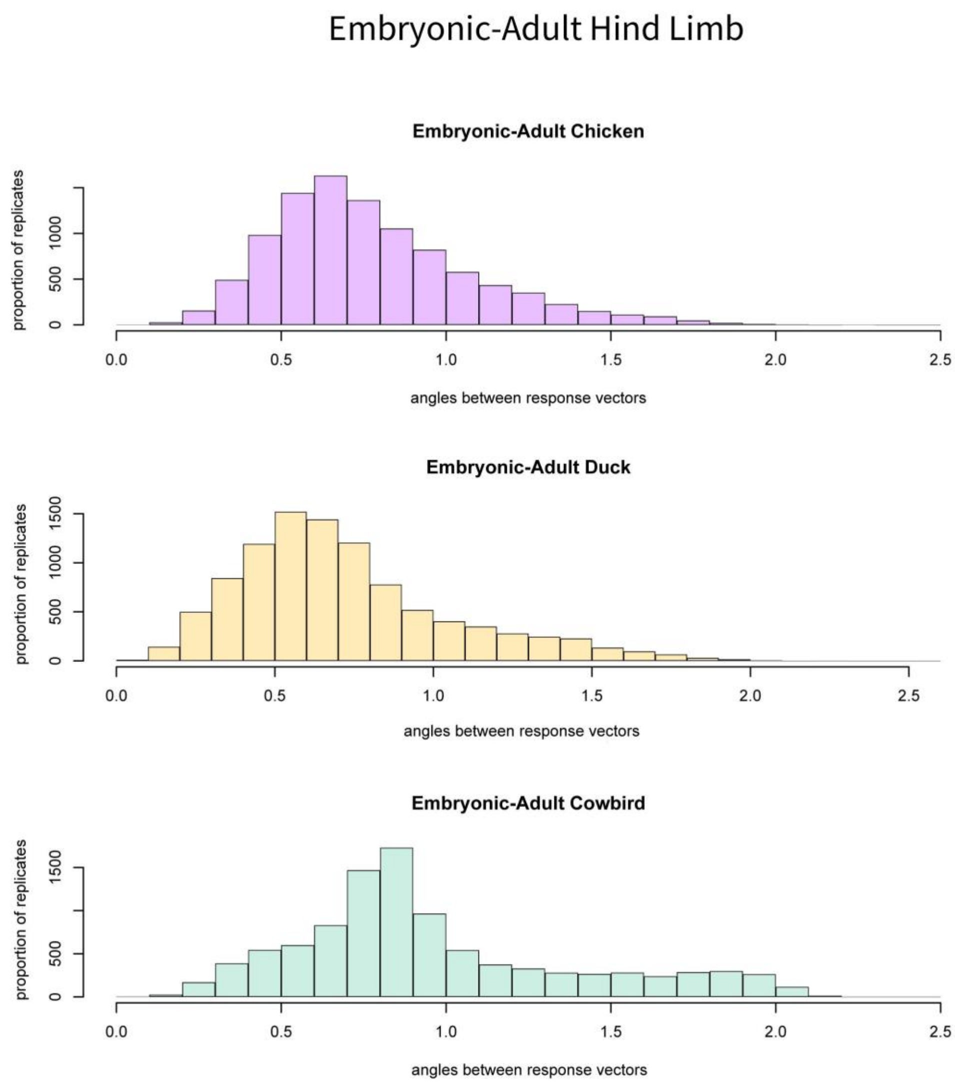

Figure 19. The distributions of angles between the response vectors of embryonic and adult chicken hind limb covariance matrices as well as those of embryonic/adult cowbird and embryonic/adult cowbird

TABLES

Table 1. Average rates of evolution for each forelimb element for flying and flightless theropods
h = humerus, r = radius, cmc = caprometacarpus

Forelimb Rates of Evolution

	h	r	cmc
flying	.02816377	.03119632	.02356052
flightless	.02984534	.03136422	.04140029

Table 2. Average rates of evolution for each hind limb element for flying and flightless theropods
f = femur, ti = tibiotarsus, ta = tarsometatarsus

Hind Limb Rates Evolution

	f	ti	ta
flying	0.01497036	0.01712726	0.02065048
flightless	0.03164137	0.02963647	0.02993559

Table 3. Average evolutionary correlations between forelimb elements
Evolutionary correlations for flying theropods are shown in purple
Evolutionary correlations for flightless theropods are shown in blue
h = humerus, r = radius, cmc = caprometacarpus

Forelimb Evolutionary Correlations

	Flying		Flightless	
	r	cmc	r	cmc
h	.02832908	.02434604		
r		.02640851		
h			.02929293	.03241897
r				.03475344

Table 4. Average evolutionary correlations between hind limb elements
Evolutionary correlations for flying theropods are shown in purple
Evolutionary correlations for flightless theropods are shown in blue
f = femur, ti = tibiotarsus, ta = tarsometatarsus

Hind Limb Correlation

	Flying		Flightless	
	ti	ta	ti	ta
f	0.01493702	0.01437016		
ti		0.01724612		
f			0.03023284	0.02978244
ti				0.02900170

Table 5: Percent of Total Variation due to Variation Among Individuals

aCH = Adult Chicken, aDU = Adult Duck, aCO = Adult Cowbird
eCH = Embryonic Chicken, eDU = Embryonic Duck, eCO = Embryonic Cowbird

	aCH length	aCH width	aDU length	aDU width	aCO length	aCO width
Humerus	98.597	85.5570	99.847	98.091	99.267	90.653
Radius	98.279	65.983	99.335	88.902	99.464	83.127
Carpo	87.816	58.426	99.373	89.153	98.502	81.713
Femur	98.363	91.838	99.459	95.942	99.286	83.811
Tibio	97.750	87.739	99.816	94.991	98.302	68.350
Tarso	98.590	89.560	NA	NA	98.456	74.865

	eCH length	eCh width	eDU length	eDu width	eDU length	eDU width
Humerus	99.017	95.888	99.267	90.653	99.791	97.745
Radius	98.762	93.303	99.464	83.127	99.879	92.126
Carpo	95.322	93.545	98.502	81.713	99.721	86.067
Femur	92.550	75.660	99.286	83.811	99.813	92.929
Tibio	99.476	97.666	98.302	68.350	99.713	95.787
Tarso	99.537	93.745	98.456	74.865	99.848	94.781

Table 6: Matrix Repeatability

	Forelimb	Hind Limb
adult chicken	0.923	0.934
adult duck	0.969	0.969
adult cowbird	0.969	0.972
embryonic chicken	0.890	0.912
embryonic duck	0.916	0.864
embryonic cowbird	0.889	0.870

Table 7: Forelimb Covariance Similarity
median angle difference = Response Vectors A – Response Vectors B
aCH = Adult Chicken, aDU = Adult Duck, aCO = Adult Cowbird
eCH = Embryonic Chicken, eDU = Embryonic Duck, eCO = Embryonic Cowbird

Forelimb

Response Vectors A	median angle	Response Vectors B	median angle	median angle difference	p-value
aCH and aDU	0.932	aCH and aCO	0.924	0.001	0.495
aCH and aDU	0.932	aDU and aCO	0.989	-0.048	0.1799
aCH and aCO	0.924	aDU and aCO	0.989	-0.054	0.2151
eCH and eDU	0.839	eCH and eCO	0.704	0.101	0.3208
eCH and eDU	0.839	eDU and eCO	0.95	-0.087	0.2963
eCH and eCO	0.704	eDU and eCO	0.95	-0.211	0.1869
aCH and eCH	0.965	aDU and eDU	0.849	0.078	0.2613
aCH and eCH	0.965	aCO and eCO	0.746	0.162	0.2017
aDU and eDU	0.849	aCO and eCO	0.746	0.072	0.3281

Hind Limb

Response Vectors A	median angle	Response Vectors B	median angle	median angle difference	p-value
aCH and aDU	0.996	aCH and aCO	0.998	-0.001	0.4212
aCH and aDU	0.996	aDU and aCO	0.999	-0.002	0.3425
aCH and aCO	0.998	aDU and aCO	0.999	0	0.4207
eCH and eDU	0.895	eCH and eCO	0.94	-0.033	0.3726
eCH and eDU	0.895	eDU and eCO	0.799	0.08	0.3034
eCH and eCO	0.94	eDU and eCO	0.799	0.119	0.2249
aCH and eCH	0.987	aDU and eDU	0.983	0.001	0.4731
aCH and eCH	0.987	aCO and eCO	0.996	-0.006	0.3293
aDU and eDU	0.983	aCO and eCO	0.996	-0.006	0.358

APPENDIX A

Flight Styles and Limb Measurements

Contents:

a. Flight Ability
flying = 2
non-flying = 1

species	flight	species	flight
Accipiter gentilis	2	Harpymimus_okladnikovi	1
Accipiter_cooperii	2	Herpetotheres cachinnans	2
Achillobator_giganticus	1	Herrerasaurus ischigualastensis	1
Acrocanthosaurus_atokensis	1	Hesperornis_regalis	1
Actophilornis albinucha	2	Heteralocha_acutirostis	2
Adasaurus_mongoliensis	1	Hexing_qingyi	1
Aechmophorus occidentalis	2	Heyuannia_huangi	1
Aegolius acadica	2	Hieraeetus fasciatus	2
Aegolius funereus	2	Himantopus himantopus	2
Aepyornis_hildebrandti	1	Himantopus leucocephalas	2
Aepyornis_maximus	1	Himantopus mexicanus	2
Aepyornis_medius	1	Hirundo rustica	2
Afrovenator_abakensis	1	Histrionicus histrionicus	2
Agriocharis ocellata	2	Hongshanornis_longicresta	2
Aix sponsa	2	Huaxiagnathus_orientalis	1
Ajaia ajaja	2	Huoshanornis_huji	2
Ajancingenia yanshini	1	Hypoleucus auritus	2
Albertosaurus_sarcophagus	1	Iberomesornis_romerali	2
Alca torda	2	Ibis_ibis	2
Alcedo atthis	2	Ibis_sp.	2
Alectoris_chukar	1	Ichthyornis_dispar	2
Alectoris_griseogularis	2	Jabiru mycteria	2
Alectrosaurus_olseni	1	Jacana spinosa	2
Alethoalaornis_agitornis	2	Jeholornis_palmapenis	2
Allosaurus fragilis	1	Jeholornis_prima	2
Alopochen aegypiacus	2	Jianchangornis_microdonta	2
Alxasaurus_elesitaiensis	1	Jibeinia_luanhera	2
Amazona farinosa	2	Jinfengopteryx_elegans	1
Anas clypeata	2	Jixiangornis_orientalis	2
Anas platyrhynchos	2	Juravenator_starki	1

Anas rubripes	2
Anas specularoides	2
Anchiornis_huxleyi	1
Anhima cornuta	2
Anhinga anhinga	2
Anneavis anneae	2
Anomalopteryx_didiformis	1
Anser caerulescens	2
Anser erythropus	2
Anser fabalis	2
Anthreptes_collaris	2
Anthropoides_paradisea	2
Anthropoides_virgo	2
Anthus correndera	2
Anthus_lutescens	2
Apsaravis_ukhaana	2
Aptenodytes patagonicus	1
Apteryx oweni	1
Apteryx_australis	1
Aptornis_defosson	1
Aptornis_otidiformis	1
Apus apus	2
Aquila chrysaetos	2
Aquila_cyaneus	2
Ara macao	2
Aramus_guarauna	2
Aramus_scolpaceus	2
Archaeopteryx lithographica	2
Archaeorhynchus_spathula	2
Archaeornithomimus_asiaticus	1
Archilochus colubris	2
Ardea cocoi	2
Ardea goliath	2
Ardea herodias	2
Ardea_sumatrana	2
Ardeola_ralloides	2
Ardeotus_australis	2
Ardeotus_kori	2
Asio flammeus	2
Asio otus	2
Astur_atricapillus	2
Atlantisia rogersi	1
Aucasaurus_garridoi	1

Kakatoe leadbeateri	2
Khaan_mckennai	1
Lagopus mutus	2
Lagopus_lagopus	2
Larus argentatus	2
Larus atricilla	2
Larus glaucesens	2
Larus leucopterus	2
Larus merinus	2
Larus_pipixcan	2
Leptoptila verreauxi	2
Leptoptilus crumeniferus	2
Leptoptilus dubius	2
Leucocarbo bougainvilli	2
Leucopternis_albicollis	2
Liaoningornis_longidigitris	2
Liliensternus_liliensterni	1
Limosa fedoa	2
Limusaurus_inextricabilis	1
Linhenykus_monodactylus	1
Linheraptor_exquisitus	1
Longchengornis_sanyanensis	2
Longicrusavis_houi	2
Longipteryx_chaoyangensis	2
Longirostravis_hani	2
Lophodytes cucullatus	2
Lophortyx gambelli	2
Lophostropheus_airelensis	1
Lophura_sp?	2
Lyrurus_tetrix	2
Macrocephalon_maleo	2
Mahakala_omnogovae	1
Majungasaurus_crenatissimus	1
Mancalla_cedrosensis	1
Mancalla_diegense	1
Masiakasaurus_knopfleri	1
Megaceryle_alcyon	2
Megadyptes antipodes	1
Megalapteryx_didinus	1
Megalosaurus_bucklandii	1
Mei_long	1
Melanerpis erythrocephalus	2
Melanitta fusca	2

Australovenator_wintonensis	1
Austroraptor_cabazai	1
Avimimus_portentosus	1
Aythya marila	2
Balaur_bondoc	1
Balearica exigua	2
Balearica pavonina	2
Bambiraptor feinbergi	1
Baptornis_advenus	1
Bartamia longicauda	2
Beipiaosaurus_inexpectus	1
Beishanlong_grandis	1
Biziura lobata	2
Bombycilla cedrorum	2
Bonasa_umbellus	2
Botaurus lentiginosus	2
Botaurus stellaris	2
Branta canadensis	2
Branta leucopsis	2
Bubo virginianus	2
Bubo_africanus	2
Bucephala albeola	2
Buceros bicornis	2
Buceros_rhinoceros	2
Budytes_flavus	2
Burhinus capensis	2
Burhinus magnirostris	2
Burhinus oedicnemus	2
Buteo jamaicensis	2
Buteo magnirostris	2
Buteo rufinus	2
Butorides striata	2
Butorides virescens	2
Cacatua galerita	2
Cairina moschata	2
Callipepla_squamata	2
Callonetta leucophrys	2
Caloenas nicobarica	2
Calyptomina viridis	2
Calyptorhynchus magnificus	2
Caprimulgus ridgwayi	2
Caprimulgus vociferus	2
Cariama cristata	2
Melanocorypha yeltoniensis	2
Meleagris gallopavo	2
Melierax metabates?	2
Menura novaehollandiae	2
Merganetta_armata	2
Mergus merganser	2
Mergus serrator	2
Mergus_australis	1
Mergus_caster	2
Messelornis neartica	2
Microcarbo melanoleucos	2
Microcaster_semitorquatus	2
Microraptor_gui	1
Microraptor_zhaoianus	1
Milvus migranus	2
Mirafa javanica	2
Momotus mexicanus	2
Monasa morphoeus	2
Mononykus_olecranus	1
Morus bassanus	2
Motacilla alba	2
Muscigralla brevicauda	2
Muscisaxicola plauinucha	2
Mycteria americana	2
Mycteria_ibis	2
Mycteria_sp.	2
Myiobius_barbatus	2
Myiophoneus caeruleus	2
Nedcolbertia justinhoffmanni	1
Neimongosaurus_yangi	1
Neophron percnopterus	2
Nestor meridionalis	2
Netta peposaca	2
Noguerornis_gonzalezi	2
Nothronychus_graffami	1
Nothura_maculosa	2
Notocarbo atriceps	2
Nqwebasaurus_thwazi	1
Numenius americanus	2
Numenius arquata	2
Numida meleagris	2
Nyctea scadiaca	2
Nycticorax sp.	2

Carnotaurus_sastrei	1	Nyctidromus albicollis	2
Casuarius bennetti	1	Oceanites oceanicus	2
Casuarius sp.	1	Oceanodroma leucorhoa	2
Casuarius_casuarius	1	Octphaps lophotes	2
Catharacta skua	2	Odontophorus guttatus	2
Cathartes aura	2	Omnivoropteryx_sinousaorum	2
Cathayornis yandica	2	Opisthocomus_hoazin	2
Cathayornis_chabuensis	2	Ornitholestes_hermanni	1
Caudipteryx_zoui	1	Ornithomimus edmontonicus	1
Centrocercus urophasianus	2	Ortalis vetula	2
Cepphus grylle	2	Otus asio	2
Ceratosaurus_nasicornis	1	Oviraptor_philoceratops	1
Ceratosaurus_roechlingi	1	Oxyura australis	2
Cerepsis novehollandiae	2	Pachyornis_elephantopus	1
Cerorhinca monocerata	2	Pachyornis_mappini	1
Certhia familiaris	2	Pachyornis_oweni	1
Ceryle_alcyon	2	Pachyornis_septentrionalis	1
Chaetura pelagica	2	Palaeoglaux_artophoron	2
Changchengornis_hengdaoziensis	2	Palaeortyx_brevipes	2
Chascacocolius_oscitans	2	Palaeortyx_gallica	2
Chauna_chavaria	2	Palaeospheniscus_patagonicus	1
Chendytes_lawi	1	Palaeospheniscus_robustus	1
Chilantaisaurus_tashuikouensis	1	Palaeotis weigelti	1
Chirostenotes_pergracilis	1	Pandion haliaetus	2
Chlamydotis undulata	2	Paraortyx lorteti	2
Chloephaga picta	2	Paraprotopteryx_gracilis	2
Chordeiles_minor	2	Paraptenodytes_antarcticus	1
Choriotus_australis	2	Parus ater	2
Chuandongocoelurus_primitivus	1	Parus montanus	2
Ciccaba virgata	2	Parus_cristatus	2
Ciconia ciconia	2	Parvicursor_remotus	1
Ciconia nigra	2	Patagona gigas	2
Ciconia_maguari	2	Patagopteryx_deferrariisi	1
Cinclus cinclus	2	Pavo cristatus	2
Circus cyaneus	2	Pelecanimimus_polyodon	1
Citipati_osmolskae	1	Pelecanoides urinatrix	2
Clangula hyemalis	2	Pelecanus erythrorhnchos	2
Cnemiornis_calcitrans	1	Pelecanus occidentalis	2
Coccyzus_americanus	2	Penelope purpascens	2
Coccyzus_erythropthalmus	2	Penelopina nigra	2
Cochlearius cochlearius	2	Pengornis_houi	2
Coelophysis bauri	1	Perdix_dauurica	2
Coelophysis rhodesiensis	1	Perdix_perdix	2

Coelophysis_kayentakatae	1
Coelurus_fragilis	1
Colaptes_cafer	2
Colinus nigrogularis	2
Colinus virginianus	2
Columba aquatrix	2
Columba cayennensis	2
Columba livia	2
Columba speciosa	2
Columbina talpacoti	2
Compsognathus longipes	1
Compsohalieus harrisi	1
Compsohalieus penicillatus	2
Compsohalieus perspicillatus	2
Comptostoma_obsoletum	2
Concavenator_corcovatus	1
Concornis_lacustris	2
Confuciusornis_dui	2
Confuciusornis_feducciai	2
Confuciusornis_jianchangensis	2
Confuciusornis_sanctus	2
Confuciusornis_suniae	2
Conopophaga castaneiceps	2
Coracina caeruleogrisea	2
Coragyps atratus	2
Corcorax melanorhamphus	2
Coturnix coturnix	2
Coturnix delegorguei	2
Coturnix_japonica	2
Crax alberti	2
Crax mitu	2
Crax pauxi	2
Crotophaga sulcirostris	2
Crypturellus boucardi	2
Crypturellus_noctivagus	2
Cygnus atratus	2
Cygnus columbianus?	2
Cygnus cygnus	2
Dacelo novaeguineae	2
Dactylortyx_thoracicus	2
Dalianraptor_cuhe	2
Dalingheornis_liweii	2
Dapingfangornis_sentisorhinus	2
Pernis apivorus	2
Phaethon lepturus	2
Phalacoboenus australis	2
Phalacrocorax auritus	2
Phalacrocorax bougainvilli	2
Phalacrocorax carbo	2
Phalacrocorax urile	2
Phalaropus fulicarius	2
Phalaropus lobatus	2
Phasianus_colchicus	2
Phoebetria fusca	2
Phoebetria palpebrata	2
Phoenicopterus ruber	2
Phoenicopterus_antiquorum	2
Piatnitzkysaurus_floresi	1
Picus_viridis	2
Pilherodias pileatus	2
Pionus_aterrionus	2
Pionus_senilis	2
Pitangus_sulphuratus	2
Pitta erythrogaster	2
Pityriasis_gymnocephala	2
Platalea leucoroidia	2
Platyrhinchus_mystaceus	2
Plautus alle	2
Plautus impennes	2
Plecoplerus gambensis	2
Plegadis falcinellus	2
Plegadis_sp.	2
Podargus_ocellatus	2
Podiceps auritus	2
Podiceps caspicus	2
Podiceps grisegena	2
Podiceps_occipitalis	2
Podiceps_taczanowskii	1
Podilymbus podiceps	2
Podilymbus_gigas	1
Polyborus plancus	2
Porphyrio_porphyrio	2
Praemancalla_wetmorei	1
Probisciger aterrionus	2
Procompsognathus_triassicus	1
Progne subis	2

Daption capense	2
Daspletosaurus torosus	1
Dedrocolaptes certhia	2
Deinocheirus_mirificus	1
Deinonychus antirrhopus	1
Delichon_urbica	2
Deltadromeus_agilis	1
Dendrocygna autumnalis	2
Dendrocygna_bicolor	2
Dicrurus macroceros	2
Didactylornis_jii	2
Dilong_paradoxus	1
Dilophosaurus wetherilli	1
Dilophosaurus_sinensis	1
Dinornis_gazelle	1
Dinornis_giganteus	1
Dinornis_hercules	1
Dinornis_ingens	1
Dinornis_maxiumus	1
Dinornis_novaezealandiae	1
Dinornis_robustus	1
Dinornis_sp.	1
Dinornis_struthoides	1
Dinornis_torosus	1
Diomedea chrysostoma	2
Diomedea exulans	2
Diomedea immutabilis	2
Diomedea nigripes	2
Dromaius novaehollandiae	1
Dromas ardeola	2
Dryocopus pileatus	2
Dryptosaurus_aquilunguis	1
Ducula aenea	2
Ectopistes migratorius	2
Egretta alba	2
Egretta caerulea	2
Egretta gularis	2
Egretta thula	2
Elanus leucurus	2
Elaphrosaurus_bambergi	1
Emeus_crassus	1
Emeus_huttonii	1
Empidonax flaviventris	2
Protarchaeopteryx_robusta	1
Protopteryx_fengningensis	2
Pteroglossus aracari	2
Pulsatrix perspicata	2
Pyrocephalus rubinus	2
Qiliania_graffini	2
Rahonavis_ostromi	1
Ramphastos_pileatus	2
Ramphastos_toco	2
Rapaxavis_pani	2
Recurvirostra americana	2
Regulus regulus	2
Rhea americana	1
Rhynchotus_rufescens	2
Rinchenia_mongoliensis	1
Rissa tridactyla	2
Rollandia_microptera	1
Rollandia_rolland	2
Rupicola rupicola	2
Rynchops nigra	2
Rynchops_parasiticus	2
Sagittarius serpentarius	2
Sandcoleus copiosus	1
Sapeornis_chaoyangensis	2
Sarcorhamphus papa	2
Saurophaganax_maximus	1
Saurornithoides_mongoliensis	1
Saurornitholestes_langstoni	1
Sayornis_phoebe	2
Scansoriopteryx_heilmanni	1
Scelorchilus albicollis	2
Schizooura_lii	2
Scipionyx_samniticus	1
Segisaurus_halli	1
Segnosaurus_galbinensis	1
Shanweiniao_cooperorum	2
Shenqiornis_mengi	2
Shenzhouraptor_sinensis	2
Shuvuuia_deserti	1
Similicaudipteryx_yixianensis	1
Sinocalliopteryx_gigas	1
Sinornis_santensis	2
Sinornithoides youngi	1

Eoabelisaurus_mefi	1
Eoalulavis_hoyasi	2
Eocathayornis_walkeri	2
Eoconfuciusornis_zhengi	2
Eodromaeus_murphi	1
Eoenantiornis_buhleri	2
Eoraptor lunensis	1
Epidendrosaurus_ningchengensis	1
Epidexipteryx_hui	1
Eremophila alpestris	2
Erlianosaurus_bellamanus	1
Eudocimus ruber	2
Eudromia_elegans	2
Eudyptes chrysolophus	1
Eudyptes crestatus	1
Eudyptula_minor	1
Eugenes_fulgens	2
Euryapteryx_curtus	1
Euryapteryx_exilis	1
Euryapteryx_geranoides	1
Euryapteryx_gravis	1
Euryapteryx_tane	1
Eurylaimus ochromalus	2
Eustreptospondylus_oxoniensis	1
Excalfactoria chinensis	2
Falcarius_utahensis	1
Falcipennis_falcipennis	2
Falco jugger	2
Falco sparverius	2
Florisuga_mellivora	2
Foro panarium	2
Francolinus_francolinus	2
Fratercula artica	2
Fregata aquila	2
Fregata sp.	2
Fregatta grallaria	2
Fulmarus glacialis	2
Furnarius rufus	2
Galerida_theklae	2
Gallimimus bullatus	1
Gallirallus australis	1
Gallus gallus	2
Gansus_yumenensis	2
Sinornithomimus_dongi	1
Sinornithosaurus_haoiana	1
Sinornithosaurus_millenii	1
Sinosauropteryx_prima	1
Sinovenator_changii	1
Sinraptor_dongi	1
Sinusonasus_magnodens	1
Sitta carolinensis	2
Somateria mollissima	2
Speotyto cunicularia	2
Spheniscus demersus	1
Spheniscus humboldti	1
Spheniscus mendiculus	1
Spheniscus sp.	1
Spizaetus ornatus	2
Steatornis_caripensis	2
Stercorarius_parasiticus	2
Sterna fuscata	2
Sterna hirundo	2
Sterna striata	2
Sterna_maxima	2
Stictocarbo magellanicus	2
Stictocarbo_urile	2
Strepera_graculina	2
Strigops habroptilus	1
Strix varia	2
Struthio camelus	1
Struthiomimus altus	1
Sula sp.	2
Sula variegata	2
Syntarsus_sp.	1
Szechuanosaurus_campi	1
Szechuanosaurus_zigongensis	1
Tachyeres brachyplerus	1
Tachyeres_leucocephalus	1
Tachyeres_patachonicus	2
Tachyeres_pteneres	1
Tadorna tadorna	2
Tanycolagreus_topwilsoni	1
Taraba major	2
Tarbosaurus bataar	1
Teratornis_merriami	2
Tetrao urogallus	2

Garrulax striatus	2
Garudimimus_brevipes	1
Gasosaurus_constructus	1
Gavia immer	2
Gavia sp.	2
Gavia stellata	2
Genyornis_newtoni	1
Geococcyx	2
Geococcyx californianus	2
Geotrygon montana	2
Geranospiza caerulescens	2
Gigantoraptor_erlianensis	1
Glaucis hirsuta	2
Gobipteryx_minuta	2
Gorgosaurus_libratus	1
Graciliraptor_lujiatunensis	1
Gracula religiosa	2
Grus antigone	2
Grus canadensis	2
Grus leucogeranus	2
Grus_paradisea	2
Grus_virgo	2
Guaibasaurus_candelariensis	1
Guanlong_wucaii	1
Guara rubra	2
Guttera_edouardii	2
Guttera_pucherani	2
Gymnogyps californianus	2
Gymnorhina tibicen	2
Gypaetus barbatus	2
Gyps fulvus	2
Habia rubica	2
Halcyon chloris	2
Halcyon sancta	2
Haliaeetus_leucocephalus	2
Haplocheirus_sollers	1
Harpia harpyia	2

Tetrao_urogalloides	2
Tetraogallus_altaicus	2
Tetraogallus_caucasicus	2
Tetraogallus_himalayensis	2
Tetrastes_bonasia	2
Thallaseus_maximus	2
Theristicus melanopis	2
Therizinosaurus_cheloniformis	1
Tianyuraptor_ostromi	1
Tigrisoma_lineatum	2
Tinamus major	2
Tinamus tao	2
Torvosaurus_tanneri	1
Toxostoma_rufum	2
Trichoglossus ornatus	2
Tringa flavipes	2
Trogon massena	2
Troodon_formosus	1
Turdus migratorius	2
Tympanuchus_cupido	2
Tyrannosaurus_rex	1
Tyrannus verticalis	2
Tyrannus_tyrannus	2
Tyto alba	2
Uria aalge	2
Uria lomvia	2
Vanellus chilensis	2
Velociraptor_mongoliensis	1
Vescornis_hebeiensis	2
Vorona_berivotrensis	2
Vultur gryphus	2
Xenorhynchus asiaticus	2
Xiaotingia_zhengi	1
Xixianykus_zhangi	1
Xuanhanosaurus_qilixiaensis	1
Yanornis_martini	2
Yixianornis_grabaui	2
Yixianosaurus_longimanus	2
Zemaidura macrocoura	2
Zhongjianornis_yangi	2
Zhongornis_haoae	2

b. Forelimb Measurements
h = humerus, r = radius,
cmc = carpometacarpus

species	h	r	mc	source
Accipiter cooperii	71.2	69.6	39.9	Gatesy and Middleton 1997
Accipiter gentilis	95	100	56	Gatesy and Middleton 1997
Acrocanthosaurus atokensis	370	220	116	Dececchi and Larson 2013
Acrocanthosaurus_atokensis	380	210	105	Benson and Choinier 2013
Actophilornis albinucha	48.4	52.4	34.1	Gatesy and Middleton 1997
Aechmophorus occidentalis	113.2	98.3	50.7	Gatesy and Middleton 1997
Aegolius acadica	40	44.3	19.7	Gatesy and Middleton 1997
Aegolius funereus	43.4	48.8	22	Gatesy and Middleton 1997
Agriocharis ocellata	131	116.7	64.1	Gatesy and Middleton 1997
Agriocharis ocellata	119	108	61	Gatesy and Middleton 1997
Agriocharis ocellata	125	113	64	Gatesy and Middleton 1997
Aix sponsa	138	126	83	Gatesy and Middleton 1997
Ajaia ajaja	134	151	74	Gatesy and Middleton 1997
Ajaia ajaja	129	143	69	Gatesy and Middleton 1997
Ajancingenia yanshini	135	91	42	Gatesy and Middleton 1997
Ajancingenia_yanshini	139	95	41	Benson and Choinier 2013
Albertosaurus sarcophagus	305	134	83	Dececchi and Larson 2013
Alca torda	77.2	60.1	41.6	Gatesy and Middleton 1997
Alca torda	78	61.7	41.9	Gatesy and Middleton 1997
Alca torda	77.9	60.9	40.4	Gatesy and Middleton 1997
Alcedo atthis	25	29.5	12.9	Gatesy and Middleton 1997
Alcedo atthis	19.9	23.7	9.7	Gatesy and Middleton 1997
Alethoalaornis_agitornis	29.3	26.7	12.2	Benson and Choinier 2013
Allosaurus fragilis	310	222	123	Gatesy and Middleton 1997
Allosaurus fragilis	310	222	125	Dececchi and Larson 2013
Allosaurus_fragilis	318	200	118	Benson and Choinier 2013
Alopochen aegypiacus	73	58	44.5	Gatesy and Middleton 1997
Alxasaurus elesitaiensis	375	245	111	Gatesy and Middleton 1997
Amazona farinosa	65.3	74.7	46.2	Gatesy and Middleton 1997
Amazona farinosa	66.7	77.3	47.5	Gatesy and Middleton 1997
Amazona farinosa	64.8	72.1	42.9	Gatesy and Middleton 1997
Anas clypeata	89	67	56	Gatesy and Middleton 1997
Anas platyrhynchos	74	56	45	Gatesy and Middleton 1997
Anas platyrhynchos	89	70	56	Gatesy and Middleton 1997
Anas rubripes	95	78	58	Gatesy and Middleton 1997
Anas specularoides	138	129	75	Gatesy and Middleton 1997
Anchiornis huxleyi	69	54	33.9	Dececchi and Larson 2013
Anhima cornuta	183	181	90	Gatesy and Middleton 1997

Anhima cornuta	175	192	94	Gatesy and Middleton 1997
Anhinga anhinga	108	103.1	60.5	Gatesy and Middleton 1997
Anhinga anhinga	130.5	111.8	65.2	Gatesy and Middleton 1997
Anneavis anneae	41.7	37	21.6	Gatesy and Middleton 1997
Anser caerulescens	181	164	104	Gatesy and Middleton 1997
Anser erythropus	147	131	83	Gatesy and Middleton 1997
Anser fabalis	79	64	43	Gatesy and Middleton 1997
Anthus correndera	19.9	21.2	11.2	Gatesy and Middleton 1997
Apsaravis_ukhaana	48	43	22	Benson and Choinier 2013
Aptenodytes patagonicus	117.4	84.7	72.5	Gatesy and Middleton 1997
Aptenodytes patagonicus	110	82.2	68	Gatesy and Middleton 1997
Aptenodytes patagonicus	115	83.5	71.2	Gatesy and Middleton 1997
Aptenodytes patagonicus	116	92	72	Gatesy and Middleton 1997
Apteryx oweni	39.2	17.5	5.1	Gatesy and Middleton 1997
Apus apus	12.2	17.7	20.7	Gatesy and Middleton 1997
Apus apus	12.9	16.5	20.4	Gatesy and Middleton 1997
Aquila chrysaetos	189.8	209.9	102.9	Gatesy and Middleton 1997
Aquila cyaneus	181	201	102	Gatesy and Middleton 1997
Ara macao	87.4	104.1	69.8	Gatesy and Middleton 1997
Ara macao	78.6	92.7	61.3	Gatesy and Middleton 1997
Ara macao	82.2	97.4	59	Gatesy and Middleton 1997
Aramus guarauna	103	106	58	Gatesy and Middleton 1997
Aramus guarauna	110	111	62	Gatesy and Middleton 1997
Archaeopteryx lithographica	55	53	25	Gatesy and Middleton 1997
Archaeopteryx lithographica	83	69	34.3	Gatesy and Middleton 1997
Archaeopteryx lithographica	75	65	34.4	Gatesy and Middleton 1997
Archaeopteryx lithographica	72	63	33	Gatesy and Middleton 1997
Archaeopteryx lithographica	63.5	54.4	28	Gatesy and Middleton 1997
Archaeopteryx lithographica	41.5	35	17.8	Gatesy and Middleton 1997
Archaeopteryx lithographica	83	69	38	Dececchi and Larson 2013
Archaeopteryx lithographica	63.5	54.4	28	Dececchi and Larson 2013
Archaeopteryx lithographica	41.5	35	17.8	Dececchi and Larson 2013
Archaeopteryx lithographica	57.5	53.2	24.5	Dececchi and Larson 2013
Archaeopteryx_lithographica	83	69	35	Benson and Choinier 2013
Archaeopteryx_lithographica	64	54	28	Benson and Choinier 2013
Archaeorhynchus spathula	53	54	25	Dececchi and Larson 2013
Archaeorhynchus_spathula	53	54	25	Benson and Choinier 2013
Archaeornithomimus asiaticus	276	194	100	Dececchi and Larson 2013
Archilochus colubris	3.8	4	5.2	Gatesy and Middleton 1997
Archilochus colubris	3.9	4	5.6	Gatesy and Middleton 1997
Ardea cocoi	164	174	82.8	Gatesy and Middleton 1997
Ardea goliath	201	235	107	Gatesy and Middleton 1997
Ardea goliath	197	211	96	Gatesy and Middleton 1997

Ardea herodias	195	221	102	Gatesy and Middleton 1997
Ardea herodias	190	207	100	Gatesy and Middleton 1997
Ardea herodias	188	217	101	Gatesy and Middleton 1997
Ardeola ralloides	75.7	83.4	43.2	Gatesy and Middleton 1997
Ardeotus australis	220	239	101	Gatesy and Middleton 1997
Ardeotus kori	246	262	118	Gatesy and Middleton 1997
Asio flammeus	78.1	85.5	40.9	Gatesy and Middleton 1997
Asio otus	78.2	84.9	41	Gatesy and Middleton 1997
Astur atricapillus	96	98	51.1	Gatesy and Middleton 1997
Atlantisia rogersi	20	14	9	Gatesy and Middleton 1997
Aucasaurus_garridoi	265	82	35	Benson and Choinier 2013
Australovenator_wintonensis	305	213	138.4	Benson and Choinier 2013
Aythya marila	104	88	60	Gatesy and Middleton 1997
Balaur_bondoc	117	96	41	Benson and Choinier 2013
Balearica exigua	149.5	169.8	82.2	Gatesy and Middleton 1997
Balearica pavonina	201	213	92	Gatesy and Middleton 1997
Balearica pavonina	198	206	94	Gatesy and Middleton 1997
Balearica pavonina	188	190	88	Gatesy and Middleton 1997
Bambiraptor	105	85	47.8	Dececchi and Larson 2013
Bambiraptor_feinbergi	103	85	47	Benson and Choinier 2013
Bartamia longicauda	49.8	54	30.1	Gatesy and Middleton 1997
Bartamia longicauda	49.7	53.6	31.1	Gatesy and Middleton 1997
Beishanlong grandis	465	338	169	Dececchi and Larson 2013
Beishanlong_grandis	465	338	173	Benson and Choinier 2013
Biziura lobata	185	164	104	Gatesy and Middleton 1997
Bombycilla cedrorum	20.7	24.6	13.6	Gatesy and Middleton 1997
Bonasa umbellus	49.1	41.9	28.1	Gatesy and Middleton 1997
Bonasa umbellus	51.9	43.3	27.4	Gatesy and Middleton 1997
Bonasa umbellus	49.5	42.3	27	Gatesy and Middleton 1997
Bonasa umbellus	50.8	42.3	27.7	Gatesy and Middleton 1997
Botaurus lentiginosus	114	119	67	Gatesy and Middleton 1997
Botaurus lentiginosus	113	120	65	Gatesy and Middleton 1997
Botaurus lentiginosus	105	112	68	Gatesy and Middleton 1997
Botaurus stellaris	138	144	77	Gatesy and Middleton 1997
Branta canadensis	170	153	95	Gatesy and Middleton 1997
Branta canadensis	142	127	80	Gatesy and Middleton 1997
Branta leucopsis	64	52	37	Gatesy and Middleton 1997
Bubo africanus	102	113	50	Gatesy and Middleton 1997
Bubo virginianus	130	143	65	Gatesy and Middleton 1997
Bubo virginianus	130	146	66	Gatesy and Middleton 1997
Bucephala albeola	110	88	68	Gatesy and Middleton 1997
Buceros bicornis	137	181	66.8	Gatesy and Middleton 1997
Buceros rhinoceros	133	186	67	Gatesy and Middleton 1997

Budytes flavus	17.1	20.3	11.5	Gatesy and Middleton 1997
Burhinus capensis	71.9	76.2	36.7	Gatesy and Middleton 1997
Burhinus capensis	82.4	88.7	43.4	Gatesy and Middleton 1997
Burhinus magnirostris	99.9	104.8	46.9	Gatesy and Middleton 1997
Buteo jamaicensis	118	130	66	Gatesy and Middleton 1997
Buteo jamaicensis	113.7	128.8	64.1	Gatesy and Middleton 1997
Buteo magnirostris	64	67	35	Gatesy and Middleton 1997
Buteo rufinus	114	118	61	Gatesy and Middleton 1997
Butorides striata	65.9	67.4	34.5	Gatesy and Middleton 1997
Butorides striata	62.1	65.9	34.8	Gatesy and Middleton 1997
Butorides virescens	72.4	78.2	42	Gatesy and Middleton 1997
Cacatua galerita	87.5	97	53	Gatesy and Middleton 1997
Cacatua galerita	86.2	96.7	54	Gatesy and Middleton 1997
Cairina moschata	60	50	38	Gatesy and Middleton 1997
Callipepla squamata	33.9	29.2	17.4	Gatesy and Middleton 1997
Callonetta leucophrys	168	157	90	Gatesy and Middleton 1997
Caloenas nicobarica	58.5	63	39.2	Gatesy and Middleton 1997
Calyptomina viridis	27.3	32.2	17	Gatesy and Middleton 1997
Calyptorhynchus magnificus	78.8	91	59.2	Gatesy and Middleton 1997
Caprimulgus ridgwayi	31.3	36.4	20.2	Gatesy and Middleton 1997
Caprimulgus vociferus	32	39.5	21.5	Gatesy and Middleton 1997
Caprimulgus vociferus	31.5	37	19	Gatesy and Middleton 1997
Cariama cristata	107	97	50	Gatesy and Middleton 1997
Cariama cristata	103	96	55	Gatesy and Middleton 1997
Carnotaurus sastrei	285	73	37	Gatesy and Middleton 1997
Carnotaurus sastrei	285	80	37	Dececchi and Larson 2013
Carnotaurus_sastrei	284	76	36	Benson and Choinier 2013
Casuarius bennetti	69	39	22	Gatesy and Middleton 1997
Casuarius sp.	72.3	42.4	23.8	Gatesy and Middleton 1997
Casuarius sp.	62.9	35.1	21.4	Gatesy and Middleton 1997
Catharacta skua	140.3	137	70.5	Gatesy and Middleton 1997
Cathartes aura	150	169.5	82.8	Gatesy and Middleton 1997
Cathartes aura	143.3	171.8	81.2	Gatesy and Middleton 1997
Cathartes aura	133	149	72	Gatesy and Middleton 1997
Cathayornis yandica	27	26	14	Gatesy and Middleton 1997
Cathayornis_chaubensis	34	38	15	Benson and Choinier 2013
Cathayornis_yandica	27	26	13	Benson and Choinier 2013
Caudipteryx zoui	69	56	28	Dececchi and Larson 2013
Caudipteryx zoui	72	59	28	Dececchi and Larson 2013
Caudipteryx_zoui	70	56	29	Benson and Choinier 2013
Centrocercus urophasianus	95.1	80.3	43.7	Gatesy and Middleton 1997
Centrocercus urophasianus	87.7	85	46.6	Gatesy and Middleton 1997
Cepphus grylle	60.2	49.7	34.6	Gatesy and Middleton 1997

Cepphus grylle	59.2	49.1	33.8	Gatesy and Middleton 1997
Ceratosaurus roechlingi	292	150	70	Dececchi and Larson 2013
Cerepsis novehollandiae	162	147	89	Gatesy and Middleton 1997
Cerorhinca monocerata	68.5	54.6	37.5	Gatesy and Middleton 1997
Cerorhinca monocerata	69.9	55.2	38	Gatesy and Middleton 1997
Cerorhinca monocerata	68.9	53.1	36.1	Gatesy and Middleton 1997
Certhia familiaris	12.7	15.7	9	Gatesy and Middleton 1997
Certhia familiaris	13	16.5	8.3	Gatesy and Middleton 1997
Chaetura pelagica	9.2	12.1	16.3	Gatesy and Middleton 1997
Changchengornis_hengdaoziensis	33.5	31	17	Benson and Choinier 2013
Chascacocolius oscitans	26.5	23.8	15.9	Gatesy and Middleton 1997
Chendytes lawi	68.1	24.9	24.5	Gatesy and Middleton 1997
Chlamydotis undulata	135	144	70	Gatesy and Middleton 1997
Chlamydotis undulata	109	112	58	Gatesy and Middleton 1997
Chloephaga picta	70	58	44	Gatesy and Middleton 1997
Chordeiles minor	43	49	28	Gatesy and Middleton 1997
Chordeiles minor	40	47	25.5	Gatesy and Middleton 1997
Chordeiles minor	41.2	47	26.1	Gatesy and Middleton 1997
Ciccaba virgata	77	85	37.5	Gatesy and Middleton 1997
Ciconia maguari	223	246	106	Gatesy and Middleton 1997
Ciconia nigra	206	222	113	Gatesy and Middleton 1997
Ciconia nigra	202	224	112	Gatesy and Middleton 1997
Ciconia nigra	180	205	97	Gatesy and Middleton 1997
Cinclus cinclus	20.5	23	14.2	Gatesy and Middleton 1997
Circus cyaneus	96	107	57	Gatesy and Middleton 1997
Citipati osmolskae	235	245	120	Dececchi and Larson 2013
Clangula hyemalis	163	149	95	Gatesy and Middleton 1997
Cnemiornis calcitrans	158	115.9	63.2	Gatesy and Middleton 1997
Coccyzus americanus	29.6	26.7	15.6	Gatesy and Middleton 1997
Coccyzus erythropthalmus	27.9	24.7	14.6	Gatesy and Middleton 1997
Cochlearius cochlearius	99	110	52	Gatesy and Middleton 1997
Cochlearius cochlearius	93	101	48	Gatesy and Middleton 1997
Coelophysis bauri	120	65	39	Gatesy and Middleton 1997
Coelophysis bauri	134	82	40	Gatesy and Middleton 1997
Coelophysis bauri	120	65	39.2	Dececchi and Larson 2013
Coelophysis bauri	134	82	39.7	Dececchi and Larson 2013
Coelophysis rhodesiensis	100	61	26	Dececchi and Larson 2013
Coelophysis_bauri	120	65	39	Benson and Choinier 2013
Coelophysis_rhodesiensis	100	61	26	Benson and Choinier 2013
Coelurus fragilis	119	81	53	Dececchi and Larson 2013
Coelurus_fragilis	119	81	53	Benson and Choinier 2013
Colaptes cafer	41	41.6	21.5	Gatesy and Middleton 1997
Colinus nigrogularis	32.5	26.6	17.3	Gatesy and Middleton 1997

Colinus virginianus	35.6	28.5	17.9	Gatesy and Middleton 1997
Colinus virginianus	36.1	29.1	18.9	Gatesy and Middleton 1997
Columba aquatrix	50.6	52.8	35.6	Gatesy and Middleton 1997
Columba cayennensis	39.6	42.6	28.2	Gatesy and Middleton 1997
Columba livia	44.1	47.2	33	Gatesy and Middleton 1997
Columba speciosa	42.8	43.6	29	Gatesy and Middleton 1997
Columbina talpacoti	21.2	22.2	14	Gatesy and Middleton 1997
Compsognathus	38	24.9	17.6	Dececchi and Larson 2013
Compsognathus longipes	39	24	14	Gatesy and Middleton 1997
Compsognathus longipes	56.3	41	27.3	Dececchi and Larson 2013
Compsognathus_longipes	52	41	25.4	Benson and Choinier 2013
Compsognathus_longipes	39	24.7	14	Benson and Choinier 2013
Compsohalieus harrisi	101.6	82.9	41.4	Gatesy and Middleton 1997
Compsohalieus harrisi	92	75.5	39.6	Gatesy and Middleton 1997
Compsohalieus penicillatus	147.6	156.6	65	Gatesy and Middleton 1997
Compsohalieus penicillatus	137.7	145.3	60.9	Gatesy and Middleton 1997
Compsohalieus perspicillatus	172.8	189.2	76.9	Gatesy and Middleton 1997
Comptostoma obsoletum	12.1	14.4	8.1	Gatesy and Middleton 1997
Concornis lacustris	31.1	27.4	14.1	Gatesy and Middleton 1997
Concornis_lacustris	32	30	15	Benson and Choinier 2013
Confuciusornis	47.9	38.9	21.1	Dececchi and Larson 2013
Confuciusornis feducciai	78.5	69	32	Dececchi and Larson 2013
Confuciusornis sanctus	55.5	42.7	26.7	Dececchi and Larson 2013
Confuciusornis_dui	42	37	19	Benson and Choinier 2013
Confuciusornis_feducciai	78.5	73	32	Benson and Choinier 2013
Confuciusornis_sanctus	67	54	32	Benson and Choinier 2013
Confuciusornis_suniae	51	44	25.5	Benson and Choinier 2013
Conopophaga castaneiceps	18.8	19	8.9	Gatesy and Middleton 1997
Coracina caeruleogrisea	40.6	43.8	23.5	Gatesy and Middleton 1997
Coragyps atratus	134	146	75	Gatesy and Middleton 1997
Coragyps atratus	134	155.4	75.6	Gatesy and Middleton 1997
Coragyps atratus	124	132	69	Gatesy and Middleton 1997
Corcorax melanorhamphus	54.7	55.7	32	Gatesy and Middleton 1997
Coturnix coturnix	33.6	26.7	18.8	Gatesy and Middleton 1997
Coturnix coturnix	33.8	27.1	18.7	Gatesy and Middleton 1997
Coturnix delegorguei	31.4	25.3	17.1	Gatesy and Middleton 1997
Crax alberti	109	105	53	Gatesy and Middleton 1997
Crax mitu	110	107	55	Gatesy and Middleton 1997
Crax pauxi	110	111	56	Gatesy and Middleton 1997
Crotophaga sulcirostris	33.5	25.9	16.8	Gatesy and Middleton 1997
Crypturellus boucardi	49	48.5	28.7	Gatesy and Middleton 1997
Crypturellus noctivagus	58.2	54.9	32.5	Gatesy and Middleton 1997
Cygnus atratus	269	260	132	Gatesy and Middleton 1997

Cygnus columbianus?	69	55	43	Gatesy and Middleton 1997
Cygnus cygnus	310	275	145	Gatesy and Middleton 1997
Dacelo novaeguineae	64	76.6	32.4	Gatesy and Middleton 1997
Dactylortyx thoracicus	37.4	33.4	18.9	Gatesy and Middleton 1997
Dalianraptor cuhe	52	42	23	Dececchi and Larson 2013
Dalianraptor_cuhe	52	42	23	Benson and Choinier 2013
Dalingheornis_liwei	12.1	11.1	6	Benson and Choinier 2013
Dapingfangornis_sentisorhinus	24	25.5	11	Benson and Choinier 2013
Daption capense	97.5	80.7	42.4	Gatesy and Middleton 1997
Daption capense	89.1	83.4	42.3	Gatesy and Middleton 1997
Daption capense	84	78.8	42	Gatesy and Middleton 1997
Daption capense	88	79	20	Gatesy and Middleton 1997
Daption capense	89	82	44	Gatesy and Middleton 1997
Daspletosaurus torosus	357	171	120	Gatesy and Middleton 1997
Daspletosaurus torosus	225	96	58	Gatesy and Middleton 1997
Daspletosaurus torosus	357	175	120	Dececchi and Larson 2013
Daspletosaurus_torosus	225	96	58	Benson and Choinier 2013
Daspletosaurus_torosus	357	175	120	Benson and Choinier 2013
Dedrocolaptes certhia	27.2	31.9	17.9	Gatesy and Middleton 1997
Deinocheirus mirificus	938	630	230	Gatesy and Middleton 1997
Deinocheirus_mirificus	938	630	230	Benson and Choinier 2013
Deinonychus antirrhopus	254	192	90	Gatesy and Middleton 1997
Deinonychus antirrhopus	254	190	95	Dececchi and Larson 2013
Deinonychus_antirrhopus	254	192	103	Benson and Choinier 2013
Deinonychus_antirrhopus	227	172	84	Benson and Choinier 2013
Delichon urbica	15	21.3	12	Gatesy and Middleton 1997
Dendrocygna autumnalis	95	93	49	Gatesy and Middleton 1997
Dicrurus macroceros	28.4	39.1	19.9	Gatesy and Middleton 1997
Didactylornis_jii	131	133	56	Benson and Choinier 2013
Dilophosaurus sinensis	302	175	95	Benson and Choinier 2013
Dilophosaurus wetherilli	270	192	105	Gatesy and Middleton 1997
Dilophosaurus wetherilli	285	192	105	Dececchi and Larson 2013
Dilophosaurus_wetherilli	270	192	103	Benson and Choinier 2013
Diomedea chrysostoma	264	263	104	Gatesy and Middleton 1997
Diomedea exulans	405.9	400.5	138.3	Gatesy and Middleton 1997
Diomedea exulans	438	447	150	Gatesy and Middleton 1997
Diomedea exulans	394	397	145	Gatesy and Middleton 1997
Diomedea exulans	398	405	142	Gatesy and Middleton 1997
Diomedea immutabilis	247	256	99	Gatesy and Middleton 1997
Diomedea immutabilis	257	252	102	Gatesy and Middleton 1997
Diomedea nigripes	287	287	108	Gatesy and Middleton 1997
Dromaius novaehollandiae	89	65	43	Gatesy and Middleton 1997
Dromaius novaehollandiae	92	62	45	Gatesy and Middleton 1997

Dromas ardeola	70.2	72.2	36.6	Gatesy and Middleton 1997
Dryocopus pileatus	54.5	57.7	30.5	Gatesy and Middleton 1997
Ducula aenea	55.9	57.8	36.3	Gatesy and Middleton 1997
Ectopistes migratorius	42.4	44.2	30.5	Gatesy and Middleton 1997
Egretta alba	144	166	76	Gatesy and Middleton 1997
Egretta alba	155	178	84	Gatesy and Middleton 1997
Egretta caerulea	92.4	104.8	52.8	Gatesy and Middleton 1997
Egretta gularis	100.3	108.7	56.6	Gatesy and Middleton 1997
Egretta thula	100.6	114.4	54.6	Gatesy and Middleton 1997
Egretta thula	94.1	108.5	53.4	Gatesy and Middleton 1997
Egretta thula	85.9	100.5	47.9	Gatesy and Middleton 1997
Elanus leucurus	80	90	44	Gatesy and Middleton 1997
Empidonax flaviventris	14.4	18.6	9.7	Gatesy and Middleton 1997
Eoabelisaurus_mefi	335	165	74	Benson and Choinier 2013
Eoalulavis_hoyasi	26.2	29	9.5	Benson and Choinier 2013
Eocathayornis_walkeri	23.5	25.6	14	Benson and Choinier 2013
Eoconfuciusornis_zhengi	32	32	19	Benson and Choinier 2013
Eodromaeus murphi	85	66	27	Dececchi and Larson 2013
Eodromaeus_murphi	85	66	27	Benson and Choinier 2013
Eoenantiornis_buhleri	29.5	28.7	15	Benson and Choinier 2013
Eoraptor lunensis	85	63	21	Gatesy and Middleton 1997
Eoraptor lunensis	85	63	21	Dececchi and Larson 2013
Eoraptor_lunensis	85	61	20	Benson and Choinier 2013
Epidendrosaurus_ningchengensis	17.1	15	5.2	Benson and Choinier 2013
Epidexipteryx hui	50	39.2	14	Dececchi and Larson 2013
Epidexipteryx_hui	50	39	14	Benson and Choinier 2013
Eremophila alpestris	23.2	26	14.6	Gatesy and Middleton 1997
Eremophila alpestris	23	25.8	14.1	Gatesy and Middleton 1997
Erlianosaurus bellamanus	276	220	116	Dececchi and Larson 2013
Erlianosaurus_bellamanus	276	220	116	Benson and Choinier 2013
Eudocimus ruber	92	101	54	Gatesy and Middleton 1997
Eudocimus ruber	89	96	52	Gatesy and Middleton 1997
Eudocimus ruber	92	100	55	Gatesy and Middleton 1997
Eudocimus ruber	90	97	51	Gatesy and Middleton 1997
Eudyptes chrysolophus	59.4	44.2	35.3	Gatesy and Middleton 1997
Eudyptes crestatus	59.4	44.4	37.9	Gatesy and Middleton 1997
Eudyptula minor	46.7	31.3	25.3	Gatesy and Middleton 1997
Eudyptula minor	45	30	25.5	Gatesy and Middleton 1997
Eudyptula minor	49.7	33.3	25.5	Gatesy and Middleton 1997
Eurylaimus ochromalus	20.1	22.6	12.8	Gatesy and Middleton 1997
Excalfactoria chinensis	25.9	20.3	13.8	Gatesy and Middleton 1997
Falcarius utahensis	255	184	96	Dececchi and Larson 2013
Falco jugger	88	97	59	Gatesy and Middleton 1997

Falco sparverius	45	46	26	Gatesy and Middleton 1997
Foro panarium	52.5	44.5	26.7	Gatesy and Middleton 1997
Fratercula artica	64.4	49	33.5	Gatesy and Middleton 1997
Fratercula artica	64.1	49	34.2	Gatesy and Middleton 1997
Fratercula artica	58.9	44.6	31.4	Gatesy and Middleton 1997
Fregata aquila	186	238	114	Gatesy and Middleton 1997
Fregata sp.	150	190	92	Gatesy and Middleton 1997
Fregatta grallaria	25.5	21.5	17	Gatesy and Middleton 1997
Fregatta grallaria	25.5	21.5	17	Gatesy and Middleton 1997
Fulmarus glacialis	97.2	90.3	47.5	Gatesy and Middleton 1997
Fulmarus glacialis	106	98	50	Gatesy and Middleton 1997
Fulmarus glacialis	12	96	49	Gatesy and Middleton 1997
Fulmarus glacialis	107	102	51	Gatesy and Middleton 1997
Furnarius rufus	26	26	15.3	Gatesy and Middleton 1997
Gallimimus bullatus	530	350	115	Gatesy and Middleton 1997
Gallimimus bullatus	530	350	115	Dececchi and Larson 2013
Gallimimus_bullatus	530	350	115	Benson and Choinier 2013
Gallirallus australis	53.5	37.3	28.4	Gatesy and Middleton 1997
Gallirallus australis	55.2	39	29	Gatesy and Middleton 1997
Gallirallus australis	50.5	35.1	25.7	Gatesy and Middleton 1997
Gallirallus australis	56.2	38.1	28	Gatesy and Middleton 1997
Gallirallus australis	59	38.3	29.9	Gatesy and Middleton 1997
Gallus gallus	99.5	86.5	51	Gatesy and Middleton 1997
Gansus_yumenensis	48	51	24	Benson and Choinier 2013
Gansus_yumensis	48.4	50.8	25.2	Benson and Choinier 2013
Garrulax striatus	31.5	31.5	18.2	Gatesy and Middleton 1997
Gavia immer	198	158	100.1	Gatesy and Middleton 1997
Gavia immer	200	160	106	Gatesy and Middleton 1997
Gavia immer	192	158	101	Gatesy and Middleton 1997
Gavia immer	177	144	90.5	Gatesy and Middleton 1997
Gavia immer	194	151	88	Gatesy and Middleton 1997
Gavia immer	196	155	102.5	Gatesy and Middleton 1997
Gavia immer	180	139	91.9	Gatesy and Middleton 1997
Gavia immer	187	150	96	Gatesy and Middleton 1997
Gavia immer	170	138	90.1	Gatesy and Middleton 1997
Gavia immer	198	159	104	Gatesy and Middleton 1997
Gavia immer	195	157	108	Gatesy and Middleton 1997
Gavia immer	207	167	113	Gatesy and Middleton 1997
Gavia immer	167	132	86.4	Gatesy and Middleton 1997
Gavia immer	199	156	100.8	Gatesy and Middleton 1997
Gavia immer	196	153	99.9	Gatesy and Middleton 1997
Gavia immer	192	155	102	Gatesy and Middleton 1997
Gavia immer	177	141	95.2	Gatesy and Middleton 1997

Gavia immer	195	153	99.7	Gatesy and Middleton 1997
Gavia immer	185	153	96.7	Gatesy and Middleton 1997
Gavia immer	200	160	105.4	Gatesy and Middleton 1997
Gavia immer	191	151	99.6	Gatesy and Middleton 1997
Gavia immer	194	154	102.1	Gatesy and Middleton 1997
Gavia immer	190	151	100.4	Gatesy and Middleton 1997
Gavia immer	204	163	105	Gatesy and Middleton 1997
Gavia immer	193	155	99.2	Gatesy and Middleton 1997
Gavia immer	180	145	93.3	Gatesy and Middleton 1997
Gavia immer	180	145	96	Gatesy and Middleton 1997
Gavia immer	181	154	99	Gatesy and Middleton 1997
Gavia immer	194	157	98.9	Gatesy and Middleton 1997
Gavia immer	211	167	111	Gatesy and Middleton 1997
Gavia immer	185	145	93.4	Gatesy and Middleton 1997
Gavia immer	210	165	108.8	Gatesy and Middleton 1997
Gavia immer	208	167	110	Gatesy and Middleton 1997
Gavia immer	211	164	108.5	Gatesy and Middleton 1997
Gavia immer	205	158	104.1	Gatesy and Middleton 1997
Gavia immer	184	148	95.9	Gatesy and Middleton 1997
Gavia immer	192	153	100.5	Gatesy and Middleton 1997
Gavia immer	176	139	91.4	Gatesy and Middleton 1997
Gavia immer	173	136	90.7	Gatesy and Middleton 1997
Gavia immer	208	171	109	Gatesy and Middleton 1997
Gavia sp.	182	142	91	Gatesy and Middleton 1997
Gavia sp.	176	138	91	Gatesy and Middleton 1997
Gavia stellata	140	111.4	76.7	Gatesy and Middleton 1997
Gavia stellata	138	107.8	73.1	Gatesy and Middleton 1997
Gavia stellata	136	108.6	67	Gatesy and Middleton 1997
Gavia stellata	128	104.5	70.7	Gatesy and Middleton 1997
Geococcyx	47	38	21	Gatesy and Middleton 1997
Geococcyx californianus	45.1	35.4	20	Gatesy and Middleton 1997
Geotrygon montana	34.5	37.8	24.3	Gatesy and Middleton 1997
Geranospiza caerulescens	77	80	40	Gatesy and Middleton 1997
Gigantoraptor erlianensis	700	560	450	Dececchi and Larson 2013
Gigantoraptor_erlianensis	735	636	479	Benson and Choinier 2013
Glaucis hirsuta	6.6	6.7	8.3	Gatesy and Middleton 1997
Gorgosaurus	167	96	65	Dececchi and Larson 2013
Gorgosaurus libratus	324	156	98	Gatesy and Middleton 1997
Gorgosaurus libratus	205	100	60	Gatesy and Middleton 1997
Gorgosaurus_libratus	324	156	98	Benson and Choinier 2013
Graciliraptor_lujiatunensis	105	86	54	Benson and Choinier 2013
Gracula religiosa	40.3	46.4	29.1	Gatesy and Middleton 1997
Grus antigone	277	306	125	Gatesy and Middleton 1997

Grus canadensis	214	237	108	Gatesy and Middleton 1997
Grus canadensis	235	255	121	Gatesy and Middleton 1997
Grus canadensis	208	223	97	Gatesy and Middleton 1997
Grus leucogeranus	266	287	123	Gatesy and Middleton 1997
Grus paradisea	214	231	106	Gatesy and Middleton 1997
Grus virgo	171	194	93	Gatesy and Middleton 1997
Grus virgo	215	229	104	Gatesy and Middleton 1997
Grus virgo	178	194	95	Gatesy and Middleton 1997
Guanlong wucaii	222	159	91	Dececchi and Larson 2013
Guanlong_wucaii	212	159	87	Benson and Choinier 2013
Guanlong_wucaii	212	159	87	Benson and Choinier 2013
Guara rubra	90	100	51	Gatesy and Middleton 1997
Guara rubra	91	94	50	Gatesy and Middleton 1997
Guara rubra	92	93	53	Gatesy and Middleton 1997
Guttera pucherani	74	64	38	Gatesy and Middleton 1997
Gymnogyps californianus	266	293	132	Gatesy and Middleton 1997
Gymnogyps californianus	273	315.5	140	Gatesy and Middleton 1997
Gymnogyps californianus	266	308	132	Gatesy and Middleton 1997
Gymnorhina tibicen	56	61.3	37.2	Gatesy and Middleton 1997
Gypaetus barbatus	222	233	114	Gatesy and Middleton 1997
Gyps fulvus	251	296	132	Gatesy and Middleton 1997
Habia rubica	21.7	23.2	12	Gatesy and Middleton 1997
Halcyon chloris	35.8	43.1	17.9	Gatesy and Middleton 1997
Halcyon chloris	34.9	42.9	16.8	Gatesy and Middleton 1997
Halcyon chloris	37.3	46.3	18.2	Gatesy and Middleton 1997
Halcyon sancta	30.5	36.7	15.2	Gatesy and Middleton 1997
Halcyon sancta	29.5	36.1	15	Gatesy and Middleton 1997
Haliaeetus leucocephalus	211	231	112	Gatesy and Middleton 1997
Haplocheirus sollers	104.3	86	57	Dececchi and Larson 2013
Haplocheirus_sollers	104	86	57	Benson and Choinier 2013
Harpia harpyia	182	202	88	Gatesy and Middleton 1997
Harpymimus okladnikovi	294	217	94	Dececchi and Larson 2013
Harpymimus_okladnikovi	294	217	103	Benson and Choinier 2013
Herpetotheres cachinnans	85	88	44	Gatesy and Middleton 1997
Herrerasaurus ischigualastensis	175	153	58	Gatesy and Middleton 1997
Herrerasaurus ischigualastensis	175	153	58	Dececchi and Larson 2013
Herrerasaurus_ischigualastensis	181.6	153	58	Benson and Choinier 2013
Heteralocha acutirostis	42.1	41.8	24	Gatesy and Middleton 1997
Hexing_qingyi	90	76	33	Benson and Choinier 2013
Hieraeetus fasciatus	150	168	83	Gatesy and Middleton 1997
Himantopus himantopus	51.9	54.3	31.8	Gatesy and Middleton 1997
Himantopus himantopus	56.3	59.7	35.2	Gatesy and Middleton 1997
Himantopus himantopus	59.8	62.3	36.8	Gatesy and Middleton 1997

Himantopus leucocephalas	50.4	51.1	28.7	Gatesy and Middleton 1997
Himantopus mexicanus	56.4	60	32.6	Gatesy and Middleton 1997
Hirundo rustica	14.5	21.5	12.8	Gatesy and Middleton 1997
Hirundo rustica	14.3	19.7	13.2	Gatesy and Middleton 1997
Histrionicus histrionicus	96	83	58	Gatesy and Middleton 1997
Hongshanornis_longicresta	26	22	13	Benson and Choinier 2013
Huaxiagnathus orientalis	88.2	48.6	39.2	Dececchi and Larson 2013
Huaxiagnathus_orientalis	89	53	40	Benson and Choinier 2013
Huoshanornis_huji	22	23	13	Benson and Choinier 2013
Hypoleucus auritus	152.1	160.8	72.6	Gatesy and Middleton 1997
Hypoleucus auritus	143.6	152.2	70	Gatesy and Middleton 1997
Ichthyornis_dispar	58	59	26	Benson and Choinier 2013
Jabiru mycteria	237	262	119	Gatesy and Middleton 1997
Jacana spinosa	39.8	40.4	22.6	Gatesy and Middleton 1997
Jacana spinosa	40.4	42.1	23.2	Gatesy and Middleton 1997
Jacana spinosa	37.4	40.5	22.6	Gatesy and Middleton 1997
Jeholornis prima	111.4	112.3	53.3	Dececchi and Larson 2013
Jeholornis_prima	110	106	47	Benson and Choinier 2013
Jianchangornis_microdonta	76	80	34	Benson and Choinier 2013
Jibeinia_luanhera	23.3	24.2	9.3	Benson and Choinier 2013
Jinfengopteryx elegans	49.2	42.4	21.4	Dececchi and Larson 2013
Jinfengopteryx_elegans	49	42	21.4	Benson and Choinier 2013
Jixiangornis orientalis	112	103.4	44.9	Dececchi and Larson 2013
Jixiangornis_orientalis	112	103.4	47.2	Benson and Choinier 2013
Juravenator_starki	27	19	11.5	Benson and Choinier 2013
Kakatoe leadbeateri	66.8	75.7	46.3	Gatesy and Middleton 1997
Khaan mckennai	115	110	53	Dececchi and Larson 2013
Khaan_mckennai	88	69	47	Benson and Choinier 2013
Lagopus mutus	63.4	54.1	33.5	Gatesy and Middleton 1997
Larus argentatus	139.9	148.5	78.3	Gatesy and Middleton 1997
Larus atricilla	91.7	100	52.5	Gatesy and Middleton 1997
Larus glaucesens	144	155	80	Gatesy and Middleton 1997
Larus leucopterus	118	125	67	Gatesy and Middleton 1997
Larus merinus	150.8	165	85.1	Gatesy and Middleton 1997
Larus pipixcan	79.3	87.8	48.4	Gatesy and Middleton 1997
Leptoptila verreauxi	34.2	35.4	22.9	Gatesy and Middleton 1997
Leptoptilus crumeniferus	238	299	125	Gatesy and Middleton 1997
Leptoptilus dubius	278	373	163	Gatesy and Middleton 1997
Leucocarbo bougainvilli	156.7	170.6	68.3	Gatesy and Middleton 1997
Leucocarbo bougainvilli	154.3	168.6	66.7	Gatesy and Middleton 1997
Limosa fedoa	76.4	80.9	44.8	Gatesy and Middleton 1997
Limusaurus inextricabilis	80	40	12	Dececchi and Larson 2013
Limusaurus_inextricabilis	85	45	13	Benson and Choinier 2013

Linheraptor exquisitus	155	110	63	Dececchi and Larson 2013
Linheraptor_exquisitus	157	106	63	Benson and Choinier 2013
Longchengornis_sanyanensis	27.6	29	14	Benson and Choinier 2013
Longicrusavis_houi	26	24	11.5	Benson and Choinier 2013
Longipteryx_chaoyangensis	43	45	19	Benson and Choinier 2013
Lophodytes cucullatus	64.9	53.1	39.2	Gatesy and Middleton 1997
Lophodytes cucullatus	67.8	55.5	40.8	Gatesy and Middleton 1997
Lophortyx gambelli	33.1	26.9	17.5	Gatesy and Middleton 1997
Lophostropheus airelensis	205	150	68	Dececchi and Larson 2013
Macrocephalon maleo	85	86	45.8	Gatesy and Middleton 1997
Mahakala omnogovae	40	36	18	Dececchi and Larson 2013
Mahakala_omnogovae	37.5	36	18	Benson and Choinier 2013
Majungasaurus_crenatissimus	207	55	22	Benson and Choinier 2013
Mancalla cedrosensis	73.5	29.3	15.6	Gatesy and Middleton 1997
Mancalla diegense	76.5	30.9	15.3	Gatesy and Middleton 1997
Megaceryle alcyon	46.4	55.2	25.1	Gatesy and Middleton 1997
Megadyptes antipodes	73.7	57.7	43.7	Gatesy and Middleton 1997
Mei long	42	39	27	Dececchi and Larson 2013
Melanerpis erythrocephalus	38.5	39.6	19.5	Gatesy and Middleton 1997
Melanitta fusca	53	40	27	Gatesy and Middleton 1997
Melanitta fusca	104.7	93.2	60	Gatesy and Middleton 1997
Melanitta fusca	98.3	88.5	57.3	Gatesy and Middleton 1997
Melanocorypha yeltoniensis	29.4	31.1	18.8	Gatesy and Middleton 1997
Meleagris gallopavo	144	129	73	Gatesy and Middleton 1997
Meleagris gallopavo	129	119	65	Gatesy and Middleton 1997
Meleagris gallopavo	156	138	78	Gatesy and Middleton 1997
Melierax metabates?	95	95	50	Gatesy and Middleton 1997
Menura novaehollandiae	60.4	59	33.8	Gatesy and Middleton 1997
Merganetta armata	86	62	44	Gatesy and Middleton 1997
Mergus australis	72.1	57.7	40.7	Gatesy and Middleton 1997
Mergus australis	68.3	54.8	38.7	Gatesy and Middleton 1997
Mergus caster	85	60.5	43.7	Gatesy and Middleton 1997
Mergus merganser	102.1	78.6	61.8	Gatesy and Middleton 1997
Mergus merganser	90	70	52	Gatesy and Middleton 1997
Mergus merganser	96.4	81.4	58.7	Gatesy and Middleton 1997
Mergus merganser	88.2	74.2	53.1	Gatesy and Middleton 1997
Mergus serrator	94	75	53	Gatesy and Middleton 1997
Mergus serrator	88.2	72.8	51.4	Gatesy and Middleton 1997
Mergus serrator	81.6	68.1	47.9	Gatesy and Middleton 1997
Messelornis neartica	35.5	33.5	19	Gatesy and Middleton 1997
Microcarbo melanoleucos	107.3	111.3	54.6	Gatesy and Middleton 1997
Microcarbo melanoleucos	102.9	107.3	52.3	Gatesy and Middleton 1997
Microraptor gui	46.6	43.7	25.6	Dececchi and Larson 2013

Microraptor gui	57	44	31	Dececchi and Larson 2013
Microraptor gui	83	69	45	Dececchi and Larson 2013
Microraptor zhaoianus	62.9	48.3	31.3	Dececchi and Larson 2013
Microraptor_gui	88	79	48.7	Benson and Choinier 2013
Milvus migranus	109	120	60	Gatesy and Middleton 1997
Mirafa javanica	22.1	22.9	12.6	Gatesy and Middleton 1997
Momotus mexicanus	37.7	42.1	18.3	Gatesy and Middleton 1997
Monasa morphoeus	30.7	40.4	15.4	Gatesy and Middleton 1997
Mononykus olecranus	36.6	18.1	8.6	Gatesy and Middleton 1997
Mononykus olecranus	37	18	10	Dececchi and Larson 2013
Mononykus_olecranus	37	18.2	11.9	Benson and Choinier 2013
Morus bassanus	218	185	90.2	Gatesy and Middleton 1997
Motacilla alba	19.6	23.7	13	Gatesy and Middleton 1997
Muscigralla brevicauda	17.9	19.4	10.2	Gatesy and Middleton 1997
Muscisaxicola plauinucha	22.3	28.3	17.1	Gatesy and Middleton 1997
Mycteria americana	163	195	92	Gatesy and Middleton 1997
Mycteria ibis	158	178	84	Gatesy and Middleton 1997
Mycteria ibis	176	204	96	Gatesy and Middleton 1997
Mycteria sp.	199	220	97	Gatesy and Middleton 1997
Myiobius barbatus	14.4	17.7	8.6	Gatesy and Middleton 1997
Myiophoneus caeruleus	41.5	46.6	25.3	Gatesy and Middleton 1997
Neophron percnopterus	142	156	75	Gatesy and Middleton 1997
Nestor meridionalis	65	68.3	49.3	Gatesy and Middleton 1997
Netta peposaca	78	62	36	Gatesy and Middleton 1997
Noguerornis gonzalezi	22	23.3	11.3	Gatesy and Middleton 1997
Noguerornis_gonzalezi	23	23	11	Benson and Choinier 2013
Nothronychus graffami	424	275	141	Dececchi and Larson 2013
Nothronychus_graffami	424	275	141.2	Benson and Choinier 2013
Nothura maculosa	43.3	41.3	24.7	Gatesy and Middleton 1997
Notocarbo atriceps	142.6	152.6	64.4	Gatesy and Middleton 1997
Notocarbo atriceps	138	147.2	62.8	Gatesy and Middleton 1997
Nqwebasaurus thwazi	59	44	27	Dececchi and Larson 2013
Nqwebasaurus_thwazi	58.5	44.2	26.5	Benson and Choinier 2013
Numenius americanus	100.7	108.7	55	Gatesy and Middleton 1997
Numenius arquata	94.4	100.9	53.5	Gatesy and Middleton 1997
Numenius arquata	95.6	99.1	53.5	Gatesy and Middleton 1997
Numida meleagris	79	66	38	Gatesy and Middleton 1997
Nyctea scadiaca	156	169	84	Gatesy and Middleton 1997
Nycticorax sp.	105.7	118.4	58.6	Gatesy and Middleton 1997
Nyctidromus albicollis	35	40.6	22.2	Gatesy and Middleton 1997
Oceanites oceanicus	22.5	19.5	15.5	Gatesy and Middleton 1997
Oceanites oceanicus	23	19.5	15.5	Gatesy and Middleton 1997
Oceanodroma leucorhoa	37	35	21	Gatesy and Middleton 1997

Oceanodroma leucorhoa	37.5	35.5	21	Gatesy and Middleton 1997
Octphaps lophotes	37.6	35.3	23.6	Gatesy and Middleton 1997
Odontophorus guttatus	43.8	39.3	23	Gatesy and Middleton 1997
Odontophorus guttatus	42.5	38.3	20.9	Gatesy and Middleton 1997
Opisthocomus hoazin	69	63.1	40.3	Gatesy and Middleton 1997
Opisthocomus hoazin	69.3	64.6	36.4	Gatesy and Middleton 1997
Opisthocomus hoazin	71	65	38	Gatesy and Middleton 1997
Ornitholestes hermanni	124	84	48	Dececchi and Larson 2013
Ornithomimus edmontonicus	276	206	100	Gatesy and Middleton 1997
Ornithomimus_edmontonicus	276	190	107	Benson and Choinier 2013
Ortalis vetula	60	50	27.5	Gatesy and Middleton 1997
Otus asio	54.5	58	28.5	Gatesy and Middleton 1997
Otus asio	57.5	61	30	Gatesy and Middleton 1997
Oviraptor philoceratops	185	163	107	Dececchi and Larson 2013
Oxyura australis	178	158	94.5	Gatesy and Middleton 1997
Palaeoglaux artophoron	40	49	24	Gatesy and Middleton 1997
Palaeortyx gallica	41	42.1	20.6	Gatesy and Middleton 1997
Palaeospheniscus patagonicus	75.2	57.3	51.2	Gatesy and Middleton 1997
Palaeospheniscus robustus	83.7	62.7	58.9	Gatesy and Middleton 1997
Palaeotis weigelti	117	72	34	Gatesy and Middleton 1997
Pandion haliaetus	146	178	88	Gatesy and Middleton 1997
Paraortyx lorteti	40	36.8	21.1	Gatesy and Middleton 1997
Paraprotopteryx_gracilis	22.6	22	11	Benson and Choinier 2013
Parus ater	12.7	15.1	8.7	Gatesy and Middleton 1997
Parus montanus	13.6	16.3	9	Gatesy and Middleton 1997
Patagona gigas	10.2	11.4	14.3	Gatesy and Middleton 1997
Patagopteryx_deferrariisi	60	49	22	Benson and Choinier 2013
Pavo cristatus	131	108	63	Gatesy and Middleton 1997
Pavo cristatus	126	103	61	Gatesy and Middleton 1997
Pelecanimimus_polyodon	151	166	55	Benson and Choinier 2013
Pelecanoides urinatrix	56.9	52.3	29.7	Gatesy and Middleton 1997
Pelecanoides urinatrix	44.7	34.6	25.2	Gatesy and Middleton 1997
Pelecanus erythrorhnchos	315	347	143	Gatesy and Middleton 1997
Pelecanus erythrorhnchos	317	344	150	Gatesy and Middleton 1997
Pelecanus occidentalis	271	315	126	Gatesy and Middleton 1997
Pelecanus occidentalis	268	323	125	Gatesy and Middleton 1997
Penelope purpascens	92	87	46	Gatesy and Middleton 1997
Penelopina nigra	118	113	54	Gatesy and Middleton 1997
Pengornis_houi	64.3	66.7	31	Benson and Choinier 2013
Pernis apivorus	118	125	63	Gatesy and Middleton 1997
Phaethon lepturus	818.8	83.3	42.3	Gatesy and Middleton 1997
Phaethon lepturus	85.1	86.7	43.5	Gatesy and Middleton 1997
Phaethon lepturus	83.8	85	42.5	Gatesy and Middleton 1997

Phalacoboenus australis	116	107	65	Gatesy and Middleton 1997
Phalacrocorax auritus	141.5	144.3	67.9	Gatesy and Middleton 1997
Phalacrocorax bougainvilli	153.5	163	67.6	Gatesy and Middleton 1997
Phalacrocorax carbo	160	166	76.1	Gatesy and Middleton 1997
Phalacrocorax carbo	169.3	178.9	80.8	Gatesy and Middleton 1997
Phalacrocorax carbo	155.6	165.8	75.5	Gatesy and Middleton 1997
Phalacrocorax urile	139.5	146	65.7	Gatesy and Middleton 1997
Phalaropus fulicarius	33.6	33	20.1	Gatesy and Middleton 1997
Phalaropus lobatus	28.2	28.3	18.1	Gatesy and Middleton 1997
Phoebetria fusca	242	230	98	Gatesy and Middleton 1997
Phoebetria palpebrata	235	239	92	Gatesy and Middleton 1997
Phoenicopterus antiquorum	206	218	97	Gatesy and Middleton 1997
Phoenicopterus antiquorum	193	202	92	Gatesy and Middleton 1997
Phoenicopterus ruber	188	197	88	Gatesy and Middleton 1997
Phoenicopterus ruber	212	221	105	Gatesy and Middleton 1997
Phoenicopterus ruber	182	191	87	Gatesy and Middleton 1997
Phoenicopterus ruber	204	215	97	Gatesy and Middleton 1997
Phoenicopterus ruber	180	191	87	Gatesy and Middleton 1997
Phoenicopterus ruber	191	198	93	Gatesy and Middleton 1997
Phoenicopterus ruber	196	208	94	Gatesy and Middleton 1997
Picus viridis	40.8	43.7	21.5	Gatesy and Middleton 1997
Pilherodias pileatus	66.9	70.2	36.3	Gatesy and Middleton 1997
Pionus senilis	42.9	48	33.3	Gatesy and Middleton 1997
Pionus senilis	42.1	47.8	32.5	Gatesy and Middleton 1997
Pitangus sulphuratus	30.1	39.6	18.2	Gatesy and Middleton 1997
Pitta erythrogaster	30.1	32.8	17.3	Gatesy and Middleton 1997
Pityriasis gymnocephala	37	38.4	21.3	Gatesy and Middleton 1997
Platalea leucoroidia	145	161	80	Gatesy and Middleton 1997
Platyrhinchus mystaceus	14.7	16.9	8.6	Gatesy and Middleton 1997
Plautus alle	43.2	33	22.8	Gatesy and Middleton 1997
Plautus alle	43.9	34.4	23.5	Gatesy and Middleton 1997
Plautus alle	43.2	56.2	23	Gatesy and Middleton 1997
Plautus impennes	104.2	55	45.1	Gatesy and Middleton 1997
Plautus impennes	104.2	55.3	44.3	Gatesy and Middleton 1997
Plautus impennes	106.7	54.6	44.3	Gatesy and Middleton 1997
Plautus impennes	101.3	55	43.4	Gatesy and Middleton 1997
Plautus impennes	105	56.1	43.3	Gatesy and Middleton 1997
Plecoplerus gambensis	110	89	67	Gatesy and Middleton 1997
Plegadis falcinellus	92	99	54	Gatesy and Middleton 1997
Plegadis falcinellus	95	99	55	Gatesy and Middleton 1997
Plegadis sp.	90	97	52	Gatesy and Middleton 1997
Podargus ocellatus	87.7	97	40.7	Gatesy and Middleton 1997
Podiceps auritus	77.8	68.3	34.3	Gatesy and Middleton 1997

Podiceps auritus	74.4	64.2	32.4	Gatesy and Middleton 1997
Podiceps auritus	75.3	66	31.7	Gatesy and Middleton 1997
Podiceps auritus	77.2	67.3	35.2	Gatesy and Middleton 1997
Podiceps auritus	79.7	70.3	34.3	Gatesy and Middleton 1997
Podiceps caspicus	69.6	63.4	31.9	Gatesy and Middleton 1997
Podiceps caspicus	69.2	61.1	29.8	Gatesy and Middleton 1997
Podiceps caspicus	69.4	62	31.3	Gatesy and Middleton 1997
Podiceps grisegena	117.2	102.9	46.4	Gatesy and Middleton 1997
Podiceps occipitalis	66.2	60.8	29.4	Gatesy and Middleton 1997
Podiceps occipitalis	65.6	61.1	28.8	Gatesy and Middleton 1997
Podiceps taczanowskii	71.5	64.1	30.6	Gatesy and Middleton 1997
Podiceps taczanowskii	67.1	61.1	29.1	Gatesy and Middleton 1997
Podilymbus gigas	85.8	76.6	36.9	Gatesy and Middleton 1997
Podilymbus gigas	79.7	71.8	33.7	Gatesy and Middleton 1997
Podilymbus podiceps	79.3	71.8	36.2	Gatesy and Middleton 1997
Podilymbus podiceps	67.6	60.9	30.7	Gatesy and Middleton 1997
Podilymbus podiceps	68.1	61.1	31.5	Gatesy and Middleton 1997
Podilymbus podiceps	69.9	62.7	33.2	Gatesy and Middleton 1997
Podilymbus podiceps	75.8	70	33.9	Gatesy and Middleton 1997
Podilymbus podiceps	71.7	66.4	31.8	Gatesy and Middleton 1997
Polyborus plancus	104	104	55	Gatesy and Middleton 1997
Polyborus plancus	103	102	58	Gatesy and Middleton 1997
Porphyrio porphyrio	75.5	64.4	42.6	Gatesy and Middleton 1997
Praemancalla wetmorei	82.7	35.8	15.7	Gatesy and Middleton 1997
Probisciger aterrionus	86.8	99.7	55.8	Gatesy and Middleton 1997
Probisciger aterrionus	76.8	89.6	49.5	Gatesy and Middleton 1997
Progne subis	21.8	31.2	17	Gatesy and Middleton 1997
Protarchaeopteryx robusta	88	72	44	Dececchi and Larson 2013
Protopteryx_fengningensis	27	26.3	13	Benson and Choinier 2013
Pteroglossus aracari	70	81	34	Gatesy and Middleton 1997
Pulsatrix perspicata	109	116	50	Gatesy and Middleton 1997
Pyrocephalus rubinus	17.2	20.4	11.8	Gatesy and Middleton 1997
Ramphastos pileatus	70	81	34	Gatesy and Middleton 1997
Rapaxavis_pani	22	22	8	Benson and Choinier 2013
Raptorrex	99	52	24	Dececchi and Larson 2013
Recurvirostra americana	69.5	68.8	39.8	Gatesy and Middleton 1997
Recurvirostra americana	70.4	70.7	41	Gatesy and Middleton 1997
Recurvirostra americana	65.7	66.1	39	Gatesy and Middleton 1997
Recurvirostra americana	70.4	73.9	43.5	Gatesy and Middleton 1997
Recurvirostra americana	68.9	69.3	39.9	Gatesy and Middleton 1997
Recurvirostra americana	71.7	71.8	40.7	Gatesy and Middleton 1997
Regulus regulus	9.6	12.9	7.2	Gatesy and Middleton 1997
Rhea americana	260	184	77	Gatesy and Middleton 1997

Rhea americana	281	210	78	Gatesy and Middleton 1997
Rinchenia_mongoliensis	205	180	104	Benson and Choinier 2013
Rissa tridactyla	83	88	48	Gatesy and Middleton 1997
Rollandia microptera	71.6	54.6	29	Gatesy and Middleton 1997
Rollandia microptera	67.4	52	27.6	Gatesy and Middleton 1997
Rollandia rolland	57.2	51	26.3	Gatesy and Middleton 1997
Rollandia rolland	55.7	49.9	25.3	Gatesy and Middleton 1997
Rupicola rupicola	45.3	57.5	29	Gatesy and Middleton 1997
Rynchops nigra	75	91	46	Gatesy and Middleton 1997
Rynchops parasiticus	96.1	97.2	49.4	Gatesy and Middleton 1997
Sagittarius serpentarius	183	178	89	Gatesy and Middleton 1997
Sagittarius serpentarius	179	175	86	Gatesy and Middleton 1997
Sandcoleus copiosus	46.3	41.2	25.9	Gatesy and Middleton 1997
Sapeornis angustis	93.9	91.1	42.8	Dececchi and Larson 2013
Sapeornis chaoyangensis	122.6	120.4	56.5	Dececchi and Larson 2013
Sapeornis_chaoyangensis	126	122	52.9	Benson and Choinier 2013
Sarcorhamphus papa	169	197	89	Gatesy and Middleton 1997
Sarcorhamphus papa	167.4	205.3	88.2	Gatesy and Middleton 1997
Sarcorhamphus papa	166	199	88	Gatesy and Middleton 1997
Scansoriopteryx_heilmanni	18.5	14.8	5.5	Benson and Choinier 2013
Scelorchilus albicollis	22.2	20	11.6	Gatesy and Middleton 1997
Schizooura_lii	60	57	27	Benson and Choinier 2013
Scipionyx_samniticus	26.3	17.5	10.6	Benson and Choinier 2013
Scipioynx	26.3	17.5	10.6	Dececchi and Larson 2013
Shanweiniao_cooperorum	22.43	22.5	11	Benson and Choinier 2013
Shenqiornis_mengi	45	42	21.7	Benson and Choinier 2013
Shenzhouraptor_sinensis	79.8	81	36.7	Benson and Choinier 2013
Shuvuuia_deserti	25	14	10	Benson and Choinier 2013
Similicaudipteryx	24	20.6	10.4	Dececchi and Larson 2013
Sinocalliopteryx_gigas	125	94	60	Benson and Choinier 2013
Sinornis santensis	24	22	11	Dececchi and Larson 2013
Sinornis_santensis	24	22	10.3	Benson and Choinier 2013
Sinornithoides youngi	83	59.1	35	Gatesy and Middleton 1997
Sinornithoides youngi	83	59	34	Dececchi and Larson 2013
Sinornithoides_youngi	83	59.1	37	Benson and Choinier 2013
Sinornithomimus dongi	212	145	54.7	Dececchi and Larson 2013
Sinornithomimus_dongi	212	145	54.7	Benson and Choinier 2013
Sinornithosaurus	90.8	71.3	44.3	Dececchi and Larson 2013
Sinornithosaurus millenii	134	106	63	Dececchi and Larson 2013
Sinornithosaurus_haoiana	129	100	59	Benson and Choinier 2013
Sinornithosaurus_millenii	134	100	64	Benson and Choinier 2013
Sinosauropteryx prima	36	20	17	Dececchi and Larson 2013
Sinosauropteryx_prima	35.5	21	17	Benson and Choinier 2013

Sitta carolinensis	18.3	21.4	12.8	Gatesy and Middleton 1997
Somateria mollissima	114	85	62	Gatesy and Middleton 1997
Somateria mollissima	118.5	104.7	72	Gatesy and Middleton 1997
Somateria mollissima	110	100.3	68.7	Gatesy and Middleton 1997
Speotyto cunicularia	61	73	35	Gatesy and Middleton 1997
Spheniscus demersus	67.1	47.6	39.9	Gatesy and Middleton 1997
Spheniscus humboldti	69.2	46.5	39.7	Gatesy and Middleton 1997
Spheniscus humboldti	70.8	47.9	40.3	Gatesy and Middleton 1997
Spheniscus humboldti	76.1	50.8	42.1	Gatesy and Middleton 1997
Spheniscus mendiculus	54.2	37.1	30.5	Gatesy and Middleton 1997
Spheniscus sp.	67	47	44.7	Gatesy and Middleton 1997
Spizaetus ornatus	115	129	60	Gatesy and Middleton 1997
Steatornis caripensis	73.6	105	44.3	Gatesy and Middleton 1997
Sterna fuscata	63	73	38	Gatesy and Middleton 1997
Sterna hirundo	54	62	33	Gatesy and Middleton 1997
Sterna maxima	88	106	53	Gatesy and Middleton 1997
Sterna striata	58	67	35	Gatesy and Middleton 1997
Stictocarbo magellanicus	116.6	124.2	55.7	Gatesy and Middleton 1997
Stictocarbo magellanicus	114.1	119.7	55.3	Gatesy and Middleton 1997
Stictocarbo urile	137.8	147.8	65.7	Gatesy and Middleton 1997
Stictocarbo urile	125.6	134.1	60.7	Gatesy and Middleton 1997
Strepera graculina	53.6	63.5	35.5	Gatesy and Middleton 1997
Strigops habroptilus	78.9	71.8	43.6	Gatesy and Middleton 1997
Strix varia	114	120	56	Gatesy and Middleton 1997
Strix varia	98	102	48	Gatesy and Middleton 1997
Struthio camelus	395	120	100	Gatesy and Middleton 1997
Struthio camelus	377	120	98	Gatesy and Middleton 1997
Struthio camelus	268	81	72	Gatesy and Middleton 1997
Struthio camelus	294	96.3	75.2	Gatesy and Middleton 1997
Struthiomimus altus	310	228	103	Gatesy and Middleton 1997
Struthiomimus altus	310	228	103	Dececchi and Larson 2013
Struthiomimus_altus	310	228	103	Benson and Choinier 2013
Struthiomimus_altus	395	313	123	Benson and Choinier 2013
Sula sp.	173	182	79.7	Gatesy and Middleton 1997
Sula variegata	153	156	71	Gatesy and Middleton 1997
Syntarsus sp.	100	61	26	Gatesy and Middleton 1997
Szechuanosaurus zigongensis	360	200	118	Dececchi and Larson 2013
Szechuanosaurus_zigongensis	364	203	123	Benson and Choinier 2013
Tachyeres brachyplerus	113	101	69	Gatesy and Middleton 1997
Tachyeres brachyplerus	124.1	91.7	66	Gatesy and Middleton 1997
Tachyeres brachyplerus	117.1	87.7	62.4	Gatesy and Middleton 1997
Tachyeres leucocephalus	122.5	94.4	66.3	Gatesy and Middleton 1997
Tachyeres leucocephalus	115.8	90.2	62.4	Gatesy and Middleton 1997

Tachyeres patachonicus	124.1	96.2	67.2	Gatesy and Middleton 1997
Tachyeres patachonicus	118	91.7	63.5	Gatesy and Middleton 1997
Tachyeres pteneres	132.6	95.5	68.9	Gatesy and Middleton 1997
Tachyeres pteneres	125.1	90.2	64.6	Gatesy and Middleton 1997
Tadorna tadorna	113	101	69	Gatesy and Middleton 1997
Tanycolagreus topwilsoni	198	143	81	Dececchi and Larson 2013
Tanycolagreus_topwilsoni	194	141	83	Benson and Choinier 2013
Taraba major	25.5	25.2	12.5	Gatesy and Middleton 1997
Tarbosaurus bataar	255	110	60	Gatesy and Middleton 1997
Tarbosaurus_bataar	285	123	75	Benson and Choinier 2013
Teratornis merriami	317	421	167	Gatesy and Middleton 1997
Tetrao urogallus	98.9	90	51.8	Gatesy and Middleton 1997
Tetrao urogallus	131.1	119.7	67.6	Gatesy and Middleton 1997
Theristicus melanopis	115	122	65	Gatesy and Middleton 1997
Theristicus melanopis	121	132	66	Gatesy and Middleton 1997
Therizinosaurus_cheloniformes	760	550	286.8	Benson and Choinier 2013
Tianyuraptor ostromi	129	97	57	Dececchi and Larson 2013
Tianyuraptor_ostromi	130	98	54	Benson and Choinier 2013
Tigrisoma lineatum	98.1	107.6	52.5	Gatesy and Middleton 1997
Tinamus major	75	72.2	42.6	Gatesy and Middleton 1997
Tinamus tao	80	80.9	45.8	Gatesy and Middleton 1997
Torvosaurus_tanneri	424	188	117.5	Benson and Choinier 2013
Toxostoma rufum	27.3	27.2	14.9	Gatesy and Middleton 1997
Trichoglossus ornatus	27.9	28.5	20.9	Gatesy and Middleton 1997
Trichoglossus ornatus	26	25.8	20.3	Gatesy and Middleton 1997
Trichoglossus ornatus	26.4	27.5	20.9	Gatesy and Middleton 1997
Tringa flavipes	42.7	44.1	25.5	Gatesy and Middleton 1997
Tringa flavipes	40.7	42.5	25.8	Gatesy and Middleton 1997
Trogon massena	42.8	44.7	23	Gatesy and Middleton 1997
Turdus migratorius	27.2	30	18.2	Gatesy and Middleton 1997
Tympanuchus cupido	65.6	55.4	34.9	Gatesy and Middleton 1997
Tyrannosaurus rex	385	175	113	Dececchi and Larson 2013
Tyrannosaurus_rex	385	175	113	Benson and Choinier 2013
Tyrannus tyrannus	24	32.2	17.5	Gatesy and Middleton 1997
Tyrannus tyrannus	25.3	32.8	18.1	Gatesy and Middleton 1997
Tyrannus verticalis	26.1	34.8	19.3	Gatesy and Middleton 1997
Tyto alba	83	91	43	Gatesy and Middleton 1997
Tyto alba	84	90	43	Gatesy and Middleton 1997
Unnamed Enantiornithine	31	41	18.5	Gatesy and Middleton 1997
Uria aalge	86.9	61.1	43.4	Gatesy and Middleton 1997
Uria aalge	86.3	62.5	43.3	Gatesy and Middleton 1997
Uria aalge	92	69.1	45.5	Gatesy and Middleton 1997
Uria lomvia	87.7	66.8	45.4	Gatesy and Middleton 1997

Uria lomvia	87.6	65.3	43.9	Gatesy and Middleton 1997
Uria lomvia	92.1	69.8	46.9	Gatesy and Middleton 1997
Vanellus chilensis	69.7	77.2	41.1	Gatesy and Middleton 1997
Vanellus chilensis	73.3	79.5	42.9	Gatesy and Middleton 1997
Velociraptor_mongoliensis	130	104	59.1	Benson and Choinier 2013
Vescornis_hebeiensis	22	22.5	10.5	Benson and Choinier 2013
Vultur gryphus	280.7	341	144.2	Gatesy and Middleton 1997
Vultur gryphus	280	340.6	139.5	Gatesy and Middleton 1997
Vultur gryphus	280	326	139.5	Gatesy and Middleton 1997
Vultur gryphus	260	299	131	Gatesy and Middleton 1997
Xenorhynchus asiaticus	216	245	107	Gatesy and Middleton 1997
Xiaotingia zhengi	71	63	24	Dececchi and Larson 2013
Xuanhanosaurus qilixiaensis	265	202	109	Gatesy and Middleton 1997
Xuanhanosaurus_qilixiaensis	277	212	109	Benson and Choinier 2013
Yanornis martini	40.3	35.6	17	Dececchi and Larson 2013
Yanornis_martini	79	76	33	Benson and Choinier 2013
Yixianornis grabaui	49.3	48	25.6	Dececchi and Larson 2013
Yixianornis_grabaui	48	46	24	Benson and Choinier 2013
Yixianosaurus_longimanus	89	63	36	Benson and Choinier 2013
Zemaidura macrocoura	31	32.4	21.8	Gatesy and Middleton 1997
Zhongjianornis yangi	71	73	34	Dececchi and Larson 2013
Zhongjianornis_yangi	71	73	31	Benson and Choinier 2013
Zhongornis_haoae	15.9	13.9	8.6	Benson and Choinier 2013

c. Hind Limb Measurements
f = femur, ti = tibiotarsus,
ta = tarsometatarsus

species	f	ti	ta	source
Accipiter gentilis	79	109	80	Middleton and Gatesy 2000
Achillobator giganticus	505	490	234	Dececchi and Larson 2013
Achillobator_giganticus	505	490	234.4	Benson and Choinier 2013
Acrocanthosaurus atokensis	1153	865	416	Middleton and Gatesy 2000
Acrocanthosaurus atokensis	1277	958	439	Dececchi and Larson 2013
Acrocanthosaurus_atokensis	1180	895	453	Benson and Choinier 2013
Actophilornis albinucha	36.8	96.6	71.7	Middleton and Gatesy 2000
Adasaurus_mongoliensis	273	302	141	Benson and Choinier 2013
Aechmophorus occidentalis	44.7	110.8	68	Middleton and Gatesy 2000
Aegolius acadica	30.3	42.9	60	Middleton and Gatesy 2000
Aegolius funereus	32.8	48	64	Middleton and Gatesy 2000
Aepyornis hildebrandti	320	580	303	Middleton and Gatesy 2000
Aepyornis hildebrandti	240	485	275	Middleton and Gatesy 2000

Aepyornis maximus	465	810	480	Middleton and Gatesy 2000
Aepyornis maximus	410	730	420	Middleton and Gatesy 2000
Aepyornis medius	368	680	380	Middleton and Gatesy 2000
Aepyornis medius	330	572	330	Middleton and Gatesy 2000
Afrovenator abakensis	760	687	321	Middleton and Gatesy 2000
Agriocharis ocellata	110	193	77	Middleton and Gatesy 2000
Agriocharis ocellata	101	177	74	Middleton and Gatesy 2000
Agriocharis ocellata	107	185	144.5	Middleton and Gatesy 2000
Aix sponsa	40	62	35	Middleton and Gatesy 2000
Ajaia ajaja	73	156	109	Middleton and Gatesy 2000
Ajaia ajaja	69	148	99	Middleton and Gatesy 2000
Ajancingenia yanshini	228	281	125	Middleton and Gatesy 2000
Ajancingenia_yanshini	228	281	125	Dececchi and Larson 2013
Ajancingenia_yanshini	235	303	120	Benson and Choinier 2013
Albertosaurus sarcophagus	1020	1030	590	Middleton and Gatesy 2000
Albertosaurus sarcophagus	950	970	610	Middleton and Gatesy 2000
Albertosaurus sarcophagus	1080	1030	595	Dececchi and Larson 2013
Alca torda	45.6	71	32.4	Middleton and Gatesy 2000
Alca torda	42.5	73.7	33.2	Middleton and Gatesy 2000
Alca torda	42.9	71.4	35.9	Middleton and Gatesy 2000
Alcedo atthis	16.3	24.8	8.7	Middleton and Gatesy 2000
Alcedo atthis	13.6	20.4	7.6	Middleton and Gatesy 2000
Alectoris chukar	0.322	0.435	0.243	Middleton and Gatesy 2000
Alectoris chukar	0.322	0.431	0.247	Middleton and Gatesy 2000
Alectoris griseogularis	0.311	0.443	0.246	Middleton and Gatesy 2000
Alectoris griseogularis	0.316	0.432	0.252	Middleton and Gatesy 2000
Alectrosaurus_olseni	661	722	486	Benson and Choinier 2013
Alethoalaornis_agitornis	28.3	28.8	18.3	Benson and Choinier 2013
Allosaurus fragilis	880	730	375	Middleton and Gatesy 2000
Allosaurus fragilis	850	745	372	Middleton and Gatesy 2000
Allosaurus fragilis	850	690	327	Middleton and Gatesy 2000
Allosaurus fragilis	985	810	423	Middleton and Gatesy 2000
Allosaurus fragilis	850	690	327	Dececchi and Larson 2013
Allosaurus_fragilis	742	706.5	346	Benson and Choinier 2013
Allosaurus_fragilis	973	766	402	Benson and Choinier 2013
Alopochen aegypiacus	75	140	87	Middleton and Gatesy 2000
Amazona farinosa	53.3	74.5	24.7	Middleton and Gatesy 2000
Amazona farinosa	54.8	77.3	25.8	Middleton and Gatesy 2000
Amazona farinosa	51.8	71.4	23.9	Middleton and Gatesy 2000
Anas clypeata	49	65	34	Middleton and Gatesy 2000
Anas platyrhynchos	48	78	43	Middleton and Gatesy 2000
Anas platyrhynchos	41	67	37	Middleton and Gatesy 2000
Anas rubripes	48	75	42	Middleton and Gatesy 2000

Anas specularoides	56	87	49	Middleton and Gatesy 2000
Anchiornis huxleyi	66.2	106.4	55.2	Dececchi and Larson 2013
Anchiornis_huxleyi	66.2	102.1	55.2	Benson and Choinier 2013
Anhima cornuta	99	184	126	Middleton and Gatesy 2000
Anhima cornuta	92	166	113	Middleton and Gatesy 2000
Anhinga anhinga	54.4	80.2	40.9	Middleton and Gatesy 2000
Anhinga anhinga	59.4	87.5	60	Middleton and Gatesy 2000
Anhinga anhinga	55.6	89.2	41.2	Middleton and Gatesy 2000
Anneavis anneae	27.7	43.3	23.7	Middleton and Gatesy 2000
Anomalopteryx didiformis	265	405	190	Middleton and Gatesy 2000
Anomalopteryx didiformis	235	360	190	Middleton and Gatesy 2000
Anomalopteryx didiformis	238.5	377.2	179	Middleton and Gatesy 2000
Anomalopteryx didiformis	275	427	212	Middleton and Gatesy 2000
Anser caerulescens	69	124	74	Middleton and Gatesy 2000
Anser erythropus	87	148	85	Middleton and Gatesy 2000
Anser fabalis	75	127	74	Middleton and Gatesy 2000
Anthreptes collaris	11.5	20.5	15.7	Middleton and Gatesy 2000
Anthropoides paradisea	111	270	54.9	Middleton and Gatesy 2000
Anthropoides virgo	85	202	56	Middleton and Gatesy 2000
Anthropoides virgo	112	251	232	Middleton and Gatesy 2000
Anthropoides virgo	87	199	176	Middleton and Gatesy 2000
Anthus correndera	16.2	29.3	22.4	Middleton and Gatesy 2000
Anthus lutescens	15.5	27.8	20.1	Middleton and Gatesy 2000
Aptenodytes patagonicus	92.9	170	43.2	Middleton and Gatesy 2000
Aptenodytes patagonicus	115	176	46.7	Middleton and Gatesy 2000
Aptenodytes patagonicus	100.6	186.6	47.6	Middleton and Gatesy 2000
Apteryx australis	86.7	128.1	68.7	Middleton and Gatesy 2000
Apteryx australis	99	145	77.6	Middleton and Gatesy 2000
Apteryx australis	89.5	129.9	64.9	Middleton and Gatesy 2000
Apteryx oweni	80.4	113.7	62.9	Middleton and Gatesy 2000
Apteryx oweni	72.1	103.9	56.6	Middleton and Gatesy 2000
Aptornis defosson	140	260	130	Middleton and Gatesy 2000
Aptornis otidiformis	165	227	100	Middleton and Gatesy 2000
Apus apus	18.7	25.5	10.4	Middleton and Gatesy 2000
Apus apus	16.5	24.8	11.4	Middleton and Gatesy 2000
Aquila chrysaetos	122	170	107	Middleton and Gatesy 2000
Aquila chrysaetos	127.4	168.8	104.6	Middleton and Gatesy 2000
Ara macao	63	88.4	32	Middleton and Gatesy 2000
Ara macao	58.1	78.9	29.3	Middleton and Gatesy 2000
Ara macao	62	84.3	30.2	Middleton and Gatesy 2000
Aramus scolpaceus	79	182	299	Middleton and Gatesy 2000
Aramus scolpaceus	74	167	343	Middleton and Gatesy 2000
Archaeopteryx lithographica	67	92	45	Dececchi and Larson 2013

Archaeopteryx lithographica	52.6	68.5	37	Dececchi and Larson 2013
Archaeopteryx lithographica	37	52.5	30.2	Dececchi and Larson 2013
Archaeopteryx lithographica	48	73	40	Dececchi and Larson 2013
Archaeopteryx lithographica	70	89.5	47.8	Middleton and Gatesy 2000
Archaeopteryx lithographica	61	81	40	Middleton and Gatesy 2000
Archaeopteryx lithographica	53	69	36	Middleton and Gatesy 2000
Archaeopteryx lithographica	48	71	40.5	Middleton and Gatesy 2000
Archaeopteryx lithographica	37	53	30	Middleton and Gatesy 2000
Archaeopteryx_lithographica	70	89.5	47.8	Benson and Choinier 2013
Archaeorhynchus spathula	37	42	20	Dececchi and Larson 2013
Archaeorhynchus_spathula	37	40.8	20	Benson and Choinier 2013
Archaeornithomimus asiaticus	314	401	286	Middleton and Gatesy 2000
Archaeornithomimus asiaticus	435	475	310	Dececchi and Larson 2013
Archilochus colubris	7.3	10.9	4.6	Middleton and Gatesy 2000
Archilochus colubris	6.5	10.2	4.1	Middleton and Gatesy 2000
Ardea cocoi	92	228	152	Middleton and Gatesy 2000
Ardea goliath	103	277	208	Middleton and Gatesy 2000
Ardea goliath	116	220	167	Middleton and Gatesy 2000
Ardea herodias	103.5	240	173	Middleton and Gatesy 2000
Ardea herodias	100	238	174	Middleton and Gatesy 2000
Ardea herodias	97.4	242	177	Middleton and Gatesy 2000
Ardea sumatrana	99.4	195	129	Middleton and Gatesy 2000
Asio flammeus	48.9	74.5	23	Middleton and Gatesy 2000
Asio otus	49.9	75.9	23.4	Middleton and Gatesy 2000
Atlantisia rogersi	26	42	24	Middleton and Gatesy 2000
Aublysodon sp.	1033	891	483	Middleton and Gatesy 2000
Aucasaurus_garridoi	730	620	340	Benson and Choinier 2013
Australovenator wintonensis	578	569	322	Dececchi and Larson 2013
Australovenator_wintonensis	578	567	322	Benson and Choinier 2013
Austroraptor cabazai	560	565	330	Dececchi and Larson 2013
Austroraptor_cabazai	560	565	330	Benson and Choinier 2013
Avimimus portentosus	188	257	153	Middleton and Gatesy 2000
Avimimus portentosus	188	257	153	Dececchi and Larson 2013
Avimimus_portentosus	186	255	150.3	Benson and Choinier 2013
Aythya marila	44	70	35	Middleton and Gatesy 2000
Balearica exigua	80.2	151	125.3	Middleton and Gatesy 2000
Balearica pavonina	101	268	217	Middleton and Gatesy 2000
Balearica pavonina	98	266	166	Middleton and Gatesy 2000
Balearica pavonina	92	251	194	Middleton and Gatesy 2000
Bambiraptor	118	167	77	Dececchi and Larson 2013
Bambiraptor_feinbergi	120	168	79.5	Benson and Choinier 2013
Baptornis advenus	71	191	84	Middleton and Gatesy 2000
Baptornis advenus	72	191	83	Middleton and Gatesy 2000

Baptornis_advenus	75	200	83	Benson and Choinier 2013
Bartamia longicauda	36.7	65.8	51.3	Middleton and Gatesy 2000
Bartamia longicauda	36.3	63.6	53.2	Middleton and Gatesy 2000
Beipiaosaurus inexpectus	265	275	107	Dececchi and Larson 2013
Beipiaosaurus_inexpectus	263	274	107	Benson and Choinier 2013
Beishanlong grandis	660	710	403	Dececchi and Larson 2013
Beishanlong_grandis	660	660	403	Benson and Choinier 2013
Biziura lobata	62	108	50	Middleton and Gatesy 2000
Bombycilla cedrorum	19.5	30.6	18	Middleton and Gatesy 2000
Bonasa umbellus	56.2	75	41.4	Middleton and Gatesy 2000
Bonasa umbellus	52.8	75	41.2	Middleton and Gatesy 2000
Bonasa umbellus	56.6	78	41.6	Middleton and Gatesy 2000
Bonasa umbellus	27.3	36.2	22.1	Middleton and Gatesy 2000
Bonasa umbellus	53	75.6	42.1	Middleton and Gatesy 2000
Bonasa umbellus	53	75.6	41.5	Middleton and Gatesy 2000
Botaurus lentiginosus	81	135	94	Middleton and Gatesy 2000
Botaurus lentiginosus	83	135	95	Middleton and Gatesy 2000
Botaurus lentiginosus	75	130	92	Middleton and Gatesy 2000
Botaurus stellaris	101	155	99	Middleton and Gatesy 2000
Branta canadensis	89	148	94	Middleton and Gatesy 2000
Branta canadensis	78	140	85	Middleton and Gatesy 2000
Branta leucopsis	71	123	74	Middleton and Gatesy 2000
Bubo africanus	64	106	39.7	Middleton and Gatesy 2000
Bubo virginianus	83	125	65	Middleton and Gatesy 2000
Bubo virginianus	82	124	39.9	Middleton and Gatesy 2000
Bucephala albeola	40	59	33	Middleton and Gatesy 2000
Buceros bicornis	102	138	74.5	Middleton and Gatesy 2000
Buceros rhinoceros	97	132	68.3	Middleton and Gatesy 2000
Budytes flavus	15.4	30.9	22.9	Middleton and Gatesy 2000
Burhinus capensis	48.7	102.3	88.2	Middleton and Gatesy 2000
Burhinus capensis	52.2	115.1	95.1	Middleton and Gatesy 2000
Burhinus magnirostris	58.6	142.6	129.8	Middleton and Gatesy 2000
Buteo jamaicensis	84	114	87	Middleton and Gatesy 2000
Buteo magnirostris	53	76	62	Middleton and Gatesy 2000
Buteo rufinus	71	111	74	Middleton and Gatesy 2000
Butorides striata	47.8	72	48.5	Middleton and Gatesy 2000
Butorides striata	46.8	74	46	Middleton and Gatesy 2000
Butorides virescens	51.4	85	54.4	Middleton and Gatesy 2000
Cacatua galerita	59.2	84.6	26.4	Middleton and Gatesy 2000
Cacatua galerita	58.3	83.8	26.9	Middleton and Gatesy 2000
Cairina moschata	58	90	49	Middleton and Gatesy 2000
Callipepla squamata	37.3	55.7	31.3	Middleton and Gatesy 2000
Callonetta leucophrys	33	53	32	Middleton and Gatesy 2000

Caloenas nicobarica	47.6	71.5	41.5	Middleton and Gatesy 2000
Calyptomina viridis	24	35.2	21	Middleton and Gatesy 2000
Calyptorhynchus magnificus	52.4	74.1	24.5	Middleton and Gatesy 2000
Caprimulgus ridgwayi	21.5	32.7	18.5	Middleton and Gatesy 2000
Caprimulgus vociferus	22	36	17	Middleton and Gatesy 2000
Caprimulgus vociferus	20	30.5	18.5	Middleton and Gatesy 2000
Cariama cristata	82	205	67	Middleton and Gatesy 2000
Casuarius bennetti	203	320	250	Middleton and Gatesy 2000
Casuarius casuarius	47	81.8	65.2	Middleton and Gatesy 2000
Casuarius sp.	218	350	295	Middleton and Gatesy 2000
Casuarius sp.	198	323	264	Middleton and Gatesy 2000
Catharacta skua	63	109.2	72.5	Middleton and Gatesy 2000
Cathartes aura	58	102	57	Middleton and Gatesy 2000
Cathartes aura	69.8	119.3	64.5	Middleton and Gatesy 2000
Cathayornis yandica	23	29	17	Middleton and Gatesy 2000
Cathayornis_chaubensis	32	37	19	Benson and Choinier 2013
Caudipteryx zoui	145	183	112	Dececchi and Larson 2013
Caudipteryx zoui	145	188	113	Dececchi and Larson 2013
Caudipteryx_zoui	149	196	124	Benson and Choinier 2013
Centrocercus urophasianus	70.8	91.1	44.5	Middleton and Gatesy 2000
Centrocercus urophasianus	71.4	90.9	49.2	Middleton and Gatesy 2000
Cepphus grylle	36	62.9	32.5	Middleton and Gatesy 2000
Ceratosaurus nasicornis	620	555	254	Middleton and Gatesy 2000
Ceratosaurus roechlingi	620	555	254	Dececchi and Larson 2013
Ceratosaurus_nasicornis	620	557	254	Benson and Choinier 2013
Cerepsis novehollandiae	81	146	95	Middleton and Gatesy 2000
Cerorhinca monocerata	40.8	66.8	30.4	Middleton and Gatesy 2000
Cerorhinca monocerata	41.2	66.1	30.9	Middleton and Gatesy 2000
Cerorhinca monocerata	40.3	62.6	28	Middleton and Gatesy 2000
Certhia familiaris	10.6	16.1	15.1	Middleton and Gatesy 2000
Certhia familiaris	10.8	19	15.3	Middleton and Gatesy 2000
Ceryle alcyon	25.7	35.8	10.3	Middleton and Gatesy 2000
Chaetura pelagica	15.4	23.1	11.4	Middleton and Gatesy 2000
Chaetura pelagica	9.3	15	7.6	Middleton and Gatesy 2000
Changchengornis_hengdaoziensis	33.4	35	20	Benson and Choinier 2013
Chauna chavaria	95	177	126	Middleton and Gatesy 2000
Chendytes lawi	71.3	149.2	66.8	Middleton and Gatesy 2000
Chilantaisaurus tashuikouensis	1190	954	450	Middleton and Gatesy 2000
Chilantaisaurus tashuikouensis	1190	954	460	Dececchi and Larson 2013
Chilantaisaurus_tashuikouensis	1190	954	460	Benson and Choinier 2013
Chirostenotes pergracilis	310	367	208	Middleton and Gatesy 2000
Chirostenotes pergracilis	310	367	208	Dececchi and Larson 2013
Chirostenotes_pergracilis	310	367	207	Benson and Choinier 2013

Chlamydotis undulata	72	136	91.8	Middleton and Gatesy 2000
Chlamydotis undulata	59	114	193	Middleton and Gatesy 2000
Chloephaga picta	88	159	97	Middleton and Gatesy 2000
Chordeiles minor	22.9	32.2	19	Middleton and Gatesy 2000
Chordeiles minor	27	36	17	Middleton and Gatesy 2000
Chordeiles minor	21.5	29.5	14	Middleton and Gatesy 2000
Choriotus australis	107	242	101	Middleton and Gatesy 2000
Chuandongocoelurus primitivus	200	237	122	Middleton and Gatesy 2000
Ciccaba virgata	49	77	63	Middleton and Gatesy 2000
Ciconia nigra	90	267	212	Middleton and Gatesy 2000
Ciconia nigra	86	250	218	Middleton and Gatesy 2000
Ciconia nigra	79	218	178	Middleton and Gatesy 2000
Cinclus cinclus	20	36.8	27	Middleton and Gatesy 2000
Circus cyaneus	69	103	82	Middleton and Gatesy 2000
Clangula hyemalis	40	64	32	Middleton and Gatesy 2000
Coccyzus americanus	28	39.8	26.2	Middleton and Gatesy 2000
Coccyzus erythropthalmus	26.4	36.9	24.8	Middleton and Gatesy 2000
Cochlearius cochlearius	68	119	78	Middleton and Gatesy 2000
Cochlearius cochlearius	65	112	73	Middleton and Gatesy 2000
Coelophysis bauri	245	255	150	Middleton and Gatesy 2000
Coelophysis bauri	209	224	126	Middleton and Gatesy 2000
Coelophysis bauri	203	221	120	Middleton and Gatesy 2000
Coelophysis bauri	196	207	110	Middleton and Gatesy 2000
Coelophysis bauri	173	195	120	Middleton and Gatesy 2000
Coelophysis bauri	172	199	114	Middleton and Gatesy 2000
Coelophysis bauri	164	188	108	Middleton and Gatesy 2000
Coelophysis bauri	141	157	95	Middleton and Gatesy 2000
Coelophysis bauri	135	154	85	Middleton and Gatesy 2000
Coelophysis bauri	126	147	87	Middleton and Gatesy 2000
Coelophysis bauri	126	140	81	Middleton and Gatesy 2000
Coelophysis bauri	125	138	84	Middleton and Gatesy 2000
Coelophysis bauri	123	136	82	Middleton and Gatesy 2000
Coelophysis bauri	122	136	79	Middleton and Gatesy 2000
Coelophysis bauri	118	135	84	Middleton and Gatesy 2000
Coelophysis bauri	86	104	65	Middleton and Gatesy 2000
Coelophysis bauri	209	224	126	Dececchi and Larson 2013
Coelophysis bauri	203	221	125	Dececchi and Larson 2013
Coelophysis rhodesiensis	208	223	132	Dececchi and Larson 2013
Coelophysis_bauri	209	224	126	Benson and Choinier 2013
Coelophysis_kayentakatae	272	276	180	Benson and Choinier 2013
Coelophysis_rhodesiensis	208	214	132	Benson and Choinier 2013
Coelurus_fragilis	210	255	119	Benson and Choinier 2013
Colaptes cafer	30.3	41.8	28	Middleton and Gatesy 2000

Colinus nigrogularis	36.7	50.2	29.9	Middleton and Gatesy 2000
Colinus nigrogularis	34.9	46.9	27.6	Middleton and Gatesy 2000
Colinus virginianus	37.8	52.3	30.7	Middleton and Gatesy 2000
Colinus virginianus	39.7	54	32.3	Middleton and Gatesy 2000
Columba aquatrix	41.7	53.7	26.6	Middleton and Gatesy 2000
Columba cayennensis	34.3	47.7	23.5	Middleton and Gatesy 2000
Columba livia	38.3	56.8	31.3	Middleton and Gatesy 2000
Columba speciosa	36.2	49.2	23.3	Middleton and Gatesy 2000
Columbina talpacoti	20.3	28.3	14	Middleton and Gatesy 2000
compsognathid?	235	280	160	Dececchi and Larson 2013
Compsognathus	65.8	87.2	56	Dececchi and Larson 2013
Compsognathus longipes	110	136	81	Middleton and Gatesy 2000
Compsognathus longipes	67	88	56	Middleton and Gatesy 2000
Compsognathus longipes	108	131.8	80.9	Dececchi and Larson 2013
Compsognathus_longipes	109	131	80	Benson and Choinier 2013
Compsognathus_longipes	71.5	85	54.5	Benson and Choinier 2013
Compsohalieus harrisi	71.2	146.5	72.5	Middleton and Gatesy 2000
Compsohalieus harrisi	63.9	132.9	67.3	Middleton and Gatesy 2000
Compsohalieus penicillatus	62.3	127.6	66.2	Middleton and Gatesy 2000
Compsohalieus penicillatus	57.5	119.8	62.7	Middleton and Gatesy 2000
Compsohalieus perspicillatus	74.6	136.9	70.1	Middleton and Gatesy 2000
Comptostoma obsoletum	11.2	20.7	15.6	Middleton and Gatesy 2000
Concavenator_corcovatus	550	495	280	Benson and Choinier 2013
Concornis_lacustris	25	31	22	Benson and Choinier 2013
Confuciusornis	41.8	48.7	23.2	Dececchi and Larson 2013
Confuciusornis feducciai	59	69	33.5	Dececchi and Larson 2013
Confuciusornis sanctus	46.7	53.2	24	Dececchi and Larson 2013
Confuciusornis sanctus	33	41	21	Middleton and Gatesy 2000
Confuciusornis_dui	35	39	19.5	Benson and Choinier 2013
Confuciusornis_feducciai	59	66	33.5	Benson and Choinier 2013
Confuciusornis_jianchangensis	42	45	21.3	Benson and Choinier 2013
Confuciusornis_sanctus	56	62	34	Benson and Choinier 2013
Confuciusornis_suniae	45	53	26	Benson and Choinier 2013
Conopophaga castaneiceps	20.3	35.5	27	Middleton and Gatesy 2000
Coracina caeruleogrisea	34	45.6	29.3	Middleton and Gatesy 2000
Coragyps atratus	78	128	73	Middleton and Gatesy 2000
Coragyps atratus	85.8	141.5	82	Middleton and Gatesy 2000
Corcorax melanorhamphus	44.4	79.8	63.9	Middleton and Gatesy 2000
Coturnix coturnix	34.5	42.1	25.7	Middleton and Gatesy 2000
Coturnix coturnix	34.4	44.2	26.6	Middleton and Gatesy 2000
Coturnix coturnix	0.336	0.42	0.249	Middleton and Gatesy 2000
Coturnix coturnix	0.332	0.413	0.26	Middleton and Gatesy 2000
Coturnix delegorguei	31.5	39.9	24.2	Middleton and Gatesy 2000

Coturnix japonica	0.345	0.416	0.239	Middleton and Gatesy 2000
Crax alberti	107	155	103	Middleton and Gatesy 2000
Crax mitu	106	157	110	Middleton and Gatesy 2000
Crax pauxi	110	169	113	Middleton and Gatesy 2000
Crotophaga sulcirostris	34.4	54.3	36.6	Middleton and Gatesy 2000
Crypturellus boucardi	50.7	75.9	52	Middleton and Gatesy 2000
Crypturellus noctivagus	58	86.4	59.5	Middleton and Gatesy 2000
Cygnus atratus	84	141	93	Middleton and Gatesy 2000
Cygnus columbianus?	114	212	113	Middleton and Gatesy 2000
Cygnus cygnus	107	188	110	Middleton and Gatesy 2000
Dacelo novaeguineae	36.5	54.2	24.2	Middleton and Gatesy 2000
Dalianraptor cuhe	49	68	43	Dececchi and Larson 2013
Dalianraptor_cuhe	49	65	43	Benson and Choinier 2013
Dalingheornis_liwei	10.5	13.5	8.4	Benson and Choinier 2013
Dapingfangornis_sentisorhinus	23	28	16	Benson and Choinier 2013
Daption capense	37.7	73.5	44.9	Middleton and Gatesy 2000
Daption capense	37.7	73.6	45.7	Middleton and Gatesy 2000
Daption capense	36	72	43	Middleton and Gatesy 2000
Daption capense	38	76	46	Middleton and Gatesy 2000
Daspletosaurus torosus	1000	870	490	Middleton and Gatesy 2000
Daspletosaurus torosus	930	870	555	Middleton and Gatesy 2000
Daspletosaurus torosus	655	736	448	Middleton and Gatesy 2000
Daspletosaurus_torosus	655	707	448	Benson and Choinier 2013
Daspletosaurus_torosus	1030	897	490	Benson and Choinier 2013
Dedrocolaptes certhia	24.6	33.5	26.2	Middleton and Gatesy 2000
Deinonychus antirrhopus	336	382	164	Middleton and Gatesy 2000
Deinonychus antirrhopus	331	370	168	Middleton and Gatesy 2000
Deinonychus antirrhopus	336	368	164	Dececchi and Larson 2013
Deinonychus_antirrhopus	336	368	171	Benson and Choinier 2013
Deltadromeus agilis	740	700	450	Dececchi and Larson 2013
Deltadromeus_agilis	740	700	450	Benson and Choinier 2013
Dendrocygna autumnalis	50	87	56	Middleton and Gatesy 2000
Dendrocygna bicolor	49	84	52	Middleton and Gatesy 2000
Dicrurus macroceros	21.8	34.8	22	Middleton and Gatesy 2000
Didactylornis_jii	80	88	44	Benson and Choinier 2013
Dilong paradoxus	181	199	118	Dececchi and Larson 2013
Dilong_paradoxus	179	203	113	Benson and Choinier 2013
Dilong_paradoxus	179	203	113	Benson and Choinier 2013
Dilophosaurus sinensis	590	495	312	Benson and Choinier 2013
Dilophosaurus wetherilli	557	580	300	Middleton and Gatesy 2000
Dilophosaurus wetherilli	557	555	300	Dececchi and Larson 2013
Dilophosaurus_wetherilli	557	530	300	Benson and Choinier 2013
Dilophosaurus_wetherilli	610	550	330	Benson and Choinier 2013

Dinornis gazelle	231	469.7	259	Middleton and Gatesy 2000
Dinornis giganteus	375	759	470	Middleton and Gatesy 2000
Dinornis giganteus	390.9	875.2	486.1	Middleton and Gatesy 2000
Dinornis hercules	353	779.8	420.3	Middleton and Gatesy 2000
Dinornis ingens	340	737	417	Middleton and Gatesy 2000
Dinornis maxiumus	470	990	518	Middleton and Gatesy 2000
Dinornis maxiumus	406.1	866.6	463.4	Middleton and Gatesy 2000
Dinornis novaezealandiae	340.5	701.7	368.1	Middleton and Gatesy 2000
Dinornis novaezealandiae	278	560	313	Middleton and Gatesy 2000
Dinornis novaezealandiae	280	540	296	Middleton and Gatesy 2000
Dinornis novaezealandiae	285	585	295	Middleton and Gatesy 2000
Dinornis robustus	354.5	718.6	382.6	Middleton and Gatesy 2000
Dinornis sp.	225	390	168	Middleton and Gatesy 2000
Dinornis struthoides	265	520.7	282.2	Middleton and Gatesy 2000
Dinornis struthoides	300	600	315	Middleton and Gatesy 2000
Dinornis torosus	295.3	588.4	303.1	Middleton and Gatesy 2000
Dinornis torosus	330	650	334	Middleton and Gatesy 2000
Diomedea chrysostoma	82	157	84	Middleton and Gatesy 2000
Diomedea exulans	109	224	126	Middleton and Gatesy 2000
Diomedea exulans	98	197	109	Middleton and Gatesy 2000
Diomedea exulans	99	202	107	Middleton and Gatesy 2000
Diomedea immutabilis	78	154	89	Middleton and Gatesy 2000
Diomedea immutabilis	71	142	88	Middleton and Gatesy 2000
Diomedea nigripes	75	157	94	Middleton and Gatesy 2000
Dromaeosaur - undescribed	208	243	101	Middleton and Gatesy 2000
Dromaius novaehollandiae	227	415	385	Middleton and Gatesy 2000
Dromaius novaehollandiae	225	400	375	Middleton and Gatesy 2000
Dromaius novaehollandiae	243	465	404	Middleton and Gatesy 2000
Dromaius novaehollandiae	228	451	380	Middleton and Gatesy 2000
Dromaius novaehollandiae	241	451	407	Middleton and Gatesy 2000
Dromaius novaehollandiae	234	436	401	Middleton and Gatesy 2000
Dromaius novaehollandiae	228	403	375	Middleton and Gatesy 2000
Dromaius novaehollandiae	218	390	389	Middleton and Gatesy 2000
Dromaius novaehollandiae	225	374	354	Middleton and Gatesy 2000
Dromas ardeola	41.8	98.7	92.2	Middleton and Gatesy 2000
Dromiceiomimus brevitertius	468	578	397	Middleton and Gatesy 2000
Dromiceiomimus brevitertius	440	527	353	Middleton and Gatesy 2000
Dromiceiomimus brevitertius	440	520	370	Middleton and Gatesy 2000
Dromiceiomimus brevitertius	390	483	288	Middleton and Gatesy 2000
Dromiceiomimus brevitertius	376	511	308	Middleton and Gatesy 2000
Dryocopus pileatus	41.9	53.5	36	Middleton and Gatesy 2000
Dryptosaurus aquilunguis	787	781	380	Middleton and Gatesy 2000
Ducula aenea	43.7	56.9	28.8	Middleton and Gatesy 2000

Ectopistes migratorius	40.6	53.8	27	Middleton and Gatesy 2000
Egretta alba	75	195	148	Middleton and Gatesy 2000
Egretta alba	83	206	158	Middleton and Gatesy 2000
Egretta caerulea	53.1	121	91.3	Middleton and Gatesy 2000
Egretta gularis	57	122	88.8	Middleton and Gatesy 2000
Egretta thula	57	137	96.6	Middleton and Gatesy 2000
Egretta thula	53.6	133	90.4	Middleton and Gatesy 2000
Egretta thula	48.4	123	86.9	Middleton and Gatesy 2000
Elanus leucurus	49	64	35	Middleton and Gatesy 2000
Elaphrosaurus bambergi	529	608	391	Middleton and Gatesy 2000
Elaphrosaurus bambergi	529	608	391	Dececchi and Larson 2013
Elaphrosaurus_bambergi	529	608	391	Benson and Choinier 2013
Emeus crassus	245	435	200	Middleton and Gatesy 2000
Emeus crassus	255	422	190	Middleton and Gatesy 2000
Emeus crassus	260	460	215	Middleton and Gatesy 2000
Emeus crassus	260	450	188	Middleton and Gatesy 2000
Emeus crassus	272.8	464.2	213.6	Middleton and Gatesy 2000
Emeus crassus	285	450	225	Middleton and Gatesy 2000
Emeus crassus	287	493	220	Middleton and Gatesy 2000
Emeus huttonii	238.4	386.6	184.4	Middleton and Gatesy 2000
Emeus huttonii	244	397	187	Middleton and Gatesy 2000
Empidonax flaviventris	12.5	22.7	16.1	Middleton and Gatesy 2000
Eoabelisaurus_mefi	640	528	317	Benson and Choinier 2013
Eoconfuciusornis_zhengi	34	38.4	24	Benson and Choinier 2013
Eodromaeus murphi	160	165	100	Dececchi and Larson 2013
Eodromaeus_murphi	160	165	100	Benson and Choinier 2013
Eoenantiornis_buhleri	26.5	29.7	22.3	Benson and Choinier 2013
Eoraptor lunensis	152	157	81	Middleton and Gatesy 2000
Eoraptor lunensis	152	157	81	Dececchi and Larson 2013
Eoraptor_lunensis	154	161.5	74.5	Benson and Choinier 2013
Epidendrosaurus_ningchengensis	16.2	18.9	11.9	Benson and Choinier 2013
Epidexipteryx hui	51	63	31	Dececchi and Larson 2013
Epidexipteryx_hui	51	63	31	Benson and Choinier 2013
Eremophila alpestris	17.7	28.9	20.6	Middleton and Gatesy 2000
Eremophila alpestris	16.8	28.2	21.6	Middleton and Gatesy 2000
Eudocimus ruber	59	127	89	Middleton and Gatesy 2000
Eudocimus ruber	56	115	81	Middleton and Gatesy 2000
Eudocimus ruber	57	124	90	Middleton and Gatesy 2000
Eudocimus ruber	55	115	78	Middleton and Gatesy 2000
Eudromia elegans	56	77.1	46.6	Middleton and Gatesy 2000
Eudyptes chrysolophus	63.3	108.3	26.1	Middleton and Gatesy 2000
Eudyptes crestatus	66.5	105.6	27.2	Middleton and Gatesy 2000
Eudyptula minor	52.2	77.2	23.6	Middleton and Gatesy 2000

Eudyptula minor	48.9	73.9	22.4	Middleton and Gatesy 2000
Eudyptula minor	50.2	70.1	23.2	Middleton and Gatesy 2000
Eugenes fulgens	10.9	15.8	6	Middleton and Gatesy 2000
Euryapteryx curtus	167.6	268.8	124.7	Middleton and Gatesy 2000
Euryapteryx curtus	179	286	136	Middleton and Gatesy 2000
Euryapteryx exilis	198.2	331.7	148.4	Middleton and Gatesy 2000
Euryapteryx exilis	205	347	152	Middleton and Gatesy 2000
Euryapteryx geranoides	236.6	387.6	174.8	Middleton and Gatesy 2000
Euryapteryx geranoides	268	455	205	Middleton and Gatesy 2000
Euryapteryx geranoides	280	472	210	Middleton and Gatesy 2000
Euryapteryx geranoides	231	411	175	Middleton and Gatesy 2000
Euryapteryx gravis	280.2	475.2	209.6	Middleton and Gatesy 2000
Euryapteryx gravis	315	520	217	Middleton and Gatesy 2000
Euryapteryx tane	190.7	328	149	Middleton and Gatesy 2000
Eurylaimus ochromalus	18.5	30.9	20.3	Middleton and Gatesy 2000
Eustreptospondylus	498	479	232	Dececchi and Larson 2013
Eustreptospondylus oxoniensis	520	500	235	Middleton and Gatesy 2000
Eustreptospondylus_oxoniensis	510	495	240	Benson and Choinier 2013
Excalfactoria chinensis	27.3	33.8	21.1	Middleton and Gatesy 2000
Excalfactoria chinensis	27	30.5	19	Middleton and Gatesy 2000
Falcarius utahensis	394	430	194	Dececchi and Larson 2013
Falcipennis falcipennis	0.34	0.434	0.226	Middleton and Gatesy 2000
Falcipennis falcipennis	0.35	0.43	0.22	Middleton and Gatesy 2000
Falco jugger	70	90	56	Middleton and Gatesy 2000
Falco sparverius	36	49	33	Middleton and Gatesy 2000
Florisuga mellivora	10.4	15	5.7	Middleton and Gatesy 2000
Foro panarium	54.1	88.4	61.3	Middleton and Gatesy 2000
Francolinus francolinus	0.313	0.416	0.271	Middleton and Gatesy 2000
Francolinus francolinus	0.307	0.418	0.275	Middleton and Gatesy 2000
Fratercula artica	38.9	62.4	27.3	Middleton and Gatesy 2000
Fratercula artica	38.8	61.9	27.1	Middleton and Gatesy 2000
Fratercula artica	36.1	56.6	26	Middleton and Gatesy 2000
Fregata aquila	51	67	19	Middleton and Gatesy 2000
Fregata sp.	43.8	62.4	18	Middleton and Gatesy 2000
Fregatta grallaria	17.5	47.5	36	Middleton and Gatesy 2000
Fregatta grallaria	17.5	48	35	Middleton and Gatesy 2000
Fulmarus glacialis	41.8	76.4	44.6	Middleton and Gatesy 2000
Fulmarus glacialis	42	72	49	Middleton and Gatesy 2000
Fulmarus glacialis	41	77	47	Middleton and Gatesy 2000
Fulmarus glacialis	44	85	51	Middleton and Gatesy 2000
Furnarius rufus	22.9	39.5	31.3	Middleton and Gatesy 2000
Galerida theklae	17.6	29	22.6	Middleton and Gatesy 2000
Gallimimus	270	306	220	Dececchi and Larson 2013

Gallimimus bullatus	665	740	530	Middleton and Gatesy 2000
Gallimimus bullatus	629	695	497	Middleton and Gatesy 2000
Gallimimus bullatus	360	392	280	Middleton and Gatesy 2000
Gallimimus bullatus	267	302	225	Middleton and Gatesy 2000
Gallimimus bullatus	192	218	157	Middleton and Gatesy 2000
Gallimimus bullatus	665	740	530	Dececchi and Larson 2013
Gallimimus bullatus	371	388	229	Dececchi and Larson 2013
Gallimimus_bullatus	665	710	530	Benson and Choinier 2013
Gallimimus_bullatus	680	703	524	Benson and Choinier 2013
Gallimimus_bullatus	395	412	275	Benson and Choinier 2013
Gallimimus_bullatus	392	408	270	Benson and Choinier 2013
Gallirallus australis	72.5	102	126	Middleton and Gatesy 2000
Gallirallus australis	74.1	110.2	139	Middleton and Gatesy 2000
Gallirallus australis	67.1	99	60.2	Middleton and Gatesy 2000
Gallirallus australis	77.8	113.7	66.9	Middleton and Gatesy 2000
Gallirallus australis	76	112	58.7	Middleton and Gatesy 2000
Gallus gallus	91	128	94	Middleton and Gatesy 2000
Gallus gallus	84.6	120.6	81.8	Middleton and Gatesy 2000
Gansus_yumenensis	31	62	36	Benson and Choinier 2013
Garrulax striatus	34.2	58	42.9	Middleton and Gatesy 2000
Garudimimus_brevipes	371	388	229	Benson and Choinier 2013
Garudimimus_brevipes	499	484	249	Benson and Choinier 2013
Gasosaurus_constructus	500	381	251	Benson and Choinier 2013
Gavia immer	61.8	150	93.6	Middleton and Gatesy 2000
Gavia immer	60.3	150.4	94.2	Middleton and Gatesy 2000
Gavia immer	56.4	143.3	90.2	Middleton and Gatesy 2000
Gavia immer	51.1	134	85.3	Middleton and Gatesy 2000
Gavia immer	58	141.1	87.8	Middleton and Gatesy 2000
Gavia immer	60	146	91.7	Middleton and Gatesy 2000
Gavia immer	55.9	135	86.3	Middleton and Gatesy 2000
Gavia immer	57.7	140	87.1	Middleton and Gatesy 2000
Gavia immer	49.8	134	81.6	Middleton and Gatesy 2000
Gavia immer	60.5	155	97	Middleton and Gatesy 2000
Gavia immer	57.6	145	95	Middleton and Gatesy 2000
Gavia immer	65.9	160	101	Middleton and Gatesy 2000
Gavia immer	49.5	127	82.2	Middleton and Gatesy 2000
Gavia immer	57.3	146	92.5	Middleton and Gatesy 2000
Gavia immer	59.8	151	95	Middleton and Gatesy 2000
Gavia immer	62.1	150	93.2	Middleton and Gatesy 2000
Gavia immer	54.1	140	85	Middleton and Gatesy 2000
Gavia immer	59.1	144	91.8	Middleton and Gatesy 2000
Gavia immer	57.6	147	91.3	Middleton and Gatesy 2000
Gavia immer	57.8	149	93.6	Middleton and Gatesy 2000

Gavia immer	56.5	146	88.3	Middleton and Gatesy 2000
Gavia immer	56.5	145	92.4	Middleton and Gatesy 2000
Gavia immer	56.9	140	91	Middleton and Gatesy 2000
Gavia immer	61.3	154	95.1	Middleton and Gatesy 2000
Gavia immer	55.5	146	91.1	Middleton and Gatesy 2000
Gavia immer	52.8	135	84.3	Middleton and Gatesy 2000
Gavia immer	54.1	138	88.6	Middleton and Gatesy 2000
Gavia immer	55.9	138	88.5	Middleton and Gatesy 2000
Gavia immer	55.9	140	89.2	Middleton and Gatesy 2000
Gavia immer	63.5	154	101.8	Middleton and Gatesy 2000
Gavia immer	57.3	138	89.1	Middleton and Gatesy 2000
Gavia immer	62.3	153	100.1	Middleton and Gatesy 2000
Gavia immer	62.9	160	97.7	Middleton and Gatesy 2000
Gavia immer	65.8	155	96.1	Middleton and Gatesy 2000
Gavia immer	63.5	151	93.2	Middleton and Gatesy 2000
Gavia immer	55.3	140	88.6	Middleton and Gatesy 2000
Gavia immer	58.8	146	94.2	Middleton and Gatesy 2000
Gavia immer	53.1	131	82.9	Middleton and Gatesy 2000
Gavia immer	50.2	129	82.2	Middleton and Gatesy 2000
Gavia immer	64.2	159	98	Middleton and Gatesy 2000
Gavia sp.	51.1	131.3	83.3	Middleton and Gatesy 2000
Gavia stellata	36.7	113.6	70.9	Middleton and Gatesy 2000
Gavia stellata	38.6	113.9	71.6	Middleton and Gatesy 2000
Gavia stellata	40.3	114.4	72.4	Middleton and Gatesy 2000
Gavia stellata	38.3	110.7	70.9	Middleton and Gatesy 2000
Genyornis newtoni	340	602	374	Middleton and Gatesy 2000
Geococcyx californianus	55	85	63	Middleton and Gatesy 2000
Geococcyx californianus	53.9	85	62.7	Middleton and Gatesy 2000
Geotrygon montana	32.6	50.2	29.6	Middleton and Gatesy 2000
Geranospiza caerulescens	71	108	80	Middleton and Gatesy 2000
Gigantoraptor erlianensis	1100	1180	583	Dececchi and Larson 2013
Gigantoraptor_erlianensis	1100	1180	580	Benson and Choinier 2013
Glaucis hirsuta	9.1	12.9	5.7	Middleton and Gatesy 2000
Gobipteryx_minuta	36	57.6	25	Benson and Choinier 2013
Gorgosaurus	645	714	456	Dececchi and Larson 2013
Gorgosaurus libratus	1040	1000	594	Middleton and Gatesy 2000
Gorgosaurus libratus	1025	990	625	Middleton and Gatesy 2000
Gorgosaurus libratus	954	850	515	Middleton and Gatesy 2000
Gorgosaurus libratus	940	900	580	Middleton and Gatesy 2000
Gorgosaurus libratus	880	850	535	Middleton and Gatesy 2000
Gorgosaurus libratus	700	748	480	Middleton and Gatesy 2000
Gorgosaurus libratus	730	775	542	Middleton and Gatesy 2000
Gorgosaurus libratus	600	630	440	Middleton and Gatesy 2000

Gorgosaurus_libratus	1040	1000	594	Benson and Choinier 2013
Gracula religiosa	36.4	56.3	33.4	Middleton and Gatesy 2000
Grus antigone	140	374	179	Middleton and Gatesy 2000
Grus canadensis	118	266	179	Middleton and Gatesy 2000
Grus canadensis	126	286	332	Middleton and Gatesy 2000
Grus canadensis	113	268	236	Middleton and Gatesy 2000
Grus leucogeranus	128	357	255	Middleton and Gatesy 2000
Guaibasaurus_candelariensis	268	229	95	Benson and Choinier 2013
Guanlong wucaii	416	424	360	Dececchi and Larson 2013
Guanlong_wucaii	408	389	213	Benson and Choinier 2013
Guanlong_wucaii	408	389	213	Benson and Choinier 2013
Guara rubra	55	115	81	Middleton and Gatesy 2000
Guara rubra	58	120	80	Middleton and Gatesy 2000
Guara rubra	57	115	83	Middleton and Gatesy 2000
Guttera edouardii	78	112	77	Middleton and Gatesy 2000
Gymnogyps californianus	138.5	210	114.7	Middleton and Gatesy 2000
Gymnorhina tibicen	45.2	82.8	61.4	Middleton and Gatesy 2000
Gypaetus barbatus	111	160	92	Middleton and Gatesy 2000
Gyps fulvus	128	182	104	Middleton and Gatesy 2000
Habia rubica	19.8	31.9	23.2	Middleton and Gatesy 2000
Halcyon chloris	21	32	14.7	Middleton and Gatesy 2000
Halcyon chloris	21.3	33.7	16	Middleton and Gatesy 2000
Halcyon chloris	20.8	34.6	13.5	Middleton and Gatesy 2000
Halcyon sancta	17.7	28.6	13.3	Middleton and Gatesy 2000
Halcyon sancta	19.8	30.9	13.7	Middleton and Gatesy 2000
Haplocheirus sollers	214.3	269.3	144.6	Dececchi and Larson 2013
Haplocheirus_sollers	214	269	145	Benson and Choinier 2013
Harpia harpyia	116	168	105	Middleton and Gatesy 2000
Herpetotheres cachinnans	61	99	63	Middleton and Gatesy 2000
Herrerasaurus ischigualastensis	473	411	223	Middleton and Gatesy 2000
Herrerasaurus ischigualastensis	385	327	176	Middleton and Gatesy 2000
Herrerasaurus ischigualastensis	345	315	165	Middleton and Gatesy 2000
Herrerasaurus ischigualastensis	286	280	134	Middleton and Gatesy 2000
Herrerasaurus ischigualastensis	345	345	165	Dececchi and Larson 2013
Herrerasaurus_ischigualastensis	354	318	164.5	Benson and Choinier 2013
Herrerasaurus_ischigualastensis	482	415	221	Benson and Choinier 2013
Hesperornis regalis	99	298	136	Middleton and Gatesy 2000
Hesperornis_regalis	98	316	137	Benson and Choinier 2013
Heteralocha acutirostis	47.7	93.6	74.4	Middleton and Gatesy 2000
Heyuannia huangi	255	320	135	Dececchi and Larson 2013
Heyuannia_huangi	255	320	135	Benson and Choinier 2013
Hieraeetus fasciatus	103	145	99	Middleton and Gatesy 2000
Himantopus himantopus	31.9	114.4	104.6	Middleton and Gatesy 2000

Himantopus himantopus	33.8	135	132	Middleton and Gatesy 2000
Himantopus himantopus	34.2	129	124	Middleton and Gatesy 2000
Himantopus leucocephalas	28.7	101	78.5	Middleton and Gatesy 2000
Himantopus mexicanus	32.4	124	119	Middleton and Gatesy 2000
Hirundo rustica	12.6	20.5	11.5	Middleton and Gatesy 2000
Hirundo rustica	12.4	19.5	10.8	Middleton and Gatesy 2000
Histrionicus histrionicus	44	70	38	Middleton and Gatesy 2000
Hongshanornis_longicresta	22	36.5	22	Benson and Choinier 2013
Huaxiagnathus orientalis	163.3	183.4	109.7	Dececchi and Larson 2013
Huaxiagnathus_orientalis	164	162	107	Benson and Choinier 2013
Huoshanornis_huji	21	25.9	16	Benson and Choinier 2013
Hypoleucus auritus	59.1	110.4	64.3	Middleton and Gatesy 2000
Hypoleucus auritus	55.4	104.8	62.6	Middleton and Gatesy 2000
Iberomesornis_romerali	16.4	20	11.8	Benson and Choinier 2013
Ibis ibis	83	229	188	Middleton and Gatesy 2000
Ibis ibis	89	250	211	Middleton and Gatesy 2000
Ibis sp.	106	263	236	Middleton and Gatesy 2000
IGM100/1128	99	124	82	Benson and Choinier 2013
Jabiru mycteria	109	370	322	Middleton and Gatesy 2000
Jacana spinosa	29.2	82.6	50.8	Middleton and Gatesy 2000
Jacana spinosa	28.5	81.2	55.5	Middleton and Gatesy 2000
Jacana spinosa	27.9	75.9	54.1	Middleton and Gatesy 2000
Jeholornis prima	73.25	87.85	46.6	Dececchi and Larson 2013
Jeholornis_palmapenis	57.9	76.2	40.1	Benson and Choinier 2013
Jeholornis_prima	75	84.5	47	Benson and Choinier 2013
Jianchangornis_microdonta	60	73	35	Benson and Choinier 2013
Jibeinia_luanhera	22.2	26.9	16.3	Benson and Choinier 2013
Jinfengopteryx elegans	70.3	100.5	60	Dececchi and Larson 2013
Jinfengopteryx_elegans	70	101	61	Benson and Choinier 2013
Jixiangornis orientalis	71.9	83.2	41.3	Dececchi and Larson 2013
Jixiangornis_orientalis	71.9	83.2	41.3	Benson and Choinier 2013
Juravenator	52	58.1	32	Dececchi and Larson 2013
Juravenator_starki	52	58	34	Benson and Choinier 2013
Kakatoe leadbeateri	43.5	60.6	20.9	Middleton and Gatesy 2000
Khaan mckennai	193	240	110	Dececchi and Larson 2013
Khaan_mckennai	140	154	67	Benson and Choinier 2013
Lagopus lagopus	0.344	0.433	0.223	Middleton and Gatesy 2000
Lagopus lagopus	0.349	0.436	0.215	Middleton and Gatesy 2000
Lagopus mutus	58.5	79.5	41.2	Middleton and Gatesy 2000
Lagopus mutus	0.362	0.431	0.207	Middleton and Gatesy 2000
Lagopus mutus	0.352	0.435	0.213	Middleton and Gatesy 2000
Larus argentatus	58.3	116	70.5	Middleton and Gatesy 2000
Larus atricilla	36.7	73	51.7	Middleton and Gatesy 2000

Larus glaucesens	67	126	78	Middleton and Gatesy 2000
Larus leucopterus	55	99	60	Middleton and Gatesy 2000
Larus merinus	65.4	125.1	80.4	Middleton and Gatesy 2000
Leptoptila verreauxi	32.2	49.7	30.7	Middleton and Gatesy 2000
Leptoptilus crumeniferus	105	289	224	Middleton and Gatesy 2000
Leptoptilus dubius	122	356	282	Middleton and Gatesy 2000
Leucocarbo bougainvilli	57	125.4	68.1	Middleton and Gatesy 2000
Leucocarbo bougainvilli	56.2	123.2	66.4	Middleton and Gatesy 2000
Leucopternis albicollis	67	103	80	Middleton and Gatesy 2000
Liaoningornis_longiditris	27	32.2	15.4	Benson and Choinier 2013
Liliensternus_liliensterni	424	414.5	220	Benson and Choinier 2013
Limosa fedoa	44.5	86.4	75.9	Middleton and Gatesy 2000
Limusaurus inextricabilis	208	249	155	Dececchi and Larson 2013
Limusaurus_inextricabilis	210	239	155	Benson and Choinier 2013
Linhenykus monodactylus	70	98	69	Dececchi and Larson 2013
Linheraptor exquisitus	230	255	125	Dececchi and Larson 2013
Linheraptor_exquisitus	225	255	125	Benson and Choinier 2013
Longchengornis_sanyanensis	26	32.6	23	Benson and Choinier 2013
Longicrusavis_houi	24.3	36	21	Benson and Choinier 2013
Longipteryx_chaoyangensis	30	28.9	20	Benson and Choinier 2013
Longirostravis_hani	20	24.1	13.5	Benson and Choinier 2013
Lophodytes cucullatus	55	90	47	Middleton and Gatesy 2000
Lophortyx gambelli	37.9	55.4	32.5	Middleton and Gatesy 2000
Lophostropheus airelensis	420	400	220	Dececchi and Larson 2013
Lophura sp?	94.3	142	118	Middleton and Gatesy 2000
Lyrurus tetrix	0.345	0.431	0.224	Middleton and Gatesy 2000
Lyrurus tetrix	0.345	0.432	0.223	Middleton and Gatesy 2000
Macrocephalon maleo	85.4	127	91.1	Middleton and Gatesy 2000
Mahakala omnogovae	79	110	51	Dececchi and Larson 2013
Mahakala_omnogovae	79	110	82	Benson and Choinier 2013
Mancalla diegense	52.1	67.9	41	Middleton and Gatesy 2000
Masiakasaurus knopfleri	194	196	112	Dececchi and Larson 2013
Megadyptes antipodes	80.5	120.5	35.5	Middleton and Gatesy 2000
Megalapteryx didinus	245.7	385.3	179.4	Middleton and Gatesy 2000
Megalapteryx didinus	265	405	190	Middleton and Gatesy 2000
Megalosaurus bucklandii	700	650	393	Middleton and Gatesy 2000
Mei long	81	106	58	Dececchi and Larson 2013
Mei_long	77	100.5	58	Benson and Choinier 2013
Melanerpis erythrocephalus	30.5	40.7	27	Middleton and Gatesy 2000
Melanitta fusca	35	65	38	Middleton and Gatesy 2000
Melanitta fusca	59.1	105	51.1	Middleton and Gatesy 2000
Melanitta fusca	55.5	98.9	47.6	Middleton and Gatesy 2000
Melanocorypha yeltoniensis	23.4	36.2	25.6	Middleton and Gatesy 2000

Meleagris gallopavo	127	200	131	Middleton and Gatesy 2000
Meleagris gallopavo	119	193	138	Middleton and Gatesy 2000
Meleagris gallopavo	139	230	144	Middleton and Gatesy 2000
Melierax metabates?	71	106	87	Middleton and Gatesy 2000
Menura novaehollandiae	67.7	132	111.2	Middleton and Gatesy 2000
Mergus merganser	51.4	84	45.3	Middleton and Gatesy 2000
Mergus merganser	51.5	85.9	47.6	Middleton and Gatesy 2000
Mergus serrator	49	83	47	Middleton and Gatesy 2000
Messelornis neartica	35	63	46	Middleton and Gatesy 2000
Microcarbo melanoleucos	43.6	70.6	39.7	Middleton and Gatesy 2000
Microcarbo melanoleucos	41.2	67.4	37.8	Middleton and Gatesy 2000
Microcaster semitorquatus	69	103	87	Middleton and Gatesy 2000
Microraptor gui	46.7	63.8	39.1	Dececchi and Larson 2013
Microraptor gui	64	74	47	Dececchi and Larson 2013
Microraptor gui	97	124.4	70.1	Dececchi and Larson 2013
Microraptor zhaoianus	74.8	95.5	49.4	Dececchi and Larson 2013
Microraptor_gui	106	128.6	68	Benson and Choinier 2013
Microraptor_zhaoianus	75	90.2	47.7	Benson and Choinier 2013
Milvus migranus	57	79	53	Middleton and Gatesy 2000
Mirafa javanica	19.3	30.7	23.4	Middleton and Gatesy 2000
Momotus mexicanus	27.5	39.8	27.4	Middleton and Gatesy 2000
Monasa morphoeus	21.8	31.9	18.4	Middleton and Gatesy 2000
Morus bassanus	71.8	99.5	58.2	Middleton and Gatesy 2000
Motacilla alba	16.1	31.5	22.9	Middleton and Gatesy 2000
Muscigralla brevicauda	15.5	32.2	26.5	Middleton and Gatesy 2000
Muscisaxicola plauinucha	19.4	41.2	32.2	Middleton and Gatesy 2000
Mycteria americana	92	268	205	Middleton and Gatesy 2000
Mycteria americana	82	227	186	Middleton and Gatesy 2000
Myiobius barbatus	13.6	21.3	16.3	Middleton and Gatesy 2000
Myiophoneus caeruleus	37.3	68.4	53.1	Middleton and Gatesy 2000
Nedcolbertia_justinhoffmanni	144.8	198.9	107.4	Benson and Choinier 2013
Neimongosaurus yangi	366	310	79	Dececchi and Larson 2013
Neimongosaurus_yangi	366	310	116	Benson and Choinier 2013
Neophron percnopterus	72	113	80	Middleton and Gatesy 2000
Nestor meridionalis	53.6	87.1	36	Middleton and Gatesy 2000
Netta peposaca	51	82	40	Middleton and Gatesy 2000
Nothronychus graffami	696	654	217	Dececchi and Larson 2013
Nothronychus_graffami	696	650	232	Benson and Choinier 2013
Nothura maculosa	42.4	62.3	39	Middleton and Gatesy 2000
Notocarbo atriceps	59.6	119.6	62.6	Middleton and Gatesy 2000
Notocarbo atriceps	58	116	61	Middleton and Gatesy 2000
Nqwebasaurus thwazi	118	141	73	Dececchi and Larson 2013
Nqwebasaurus_thwazi	118	140.7	72.7	Benson and Choinier 2013

Numenius americanus	59.6	118.3	96.6	Middleton and Gatesy 2000
Numenius arquata	54.9	106.1	85.4	Middleton and Gatesy 2000
Numenius arquata	54.6	105	80.8	Middleton and Gatesy 2000
Numida meleagris	79	113	74	Middleton and Gatesy 2000
Nyctea scadiaca	88	118	64	Middleton and Gatesy 2000
Nycticorax sp.	63.5	131	97.6	Middleton and Gatesy 2000
Nyctidromus albicollis	22.6	36.9	25.5	Middleton and Gatesy 2000
Oceanites oceanicus	15	47	34	Middleton and Gatesy 2000
Oceanites oceanicus	15.5	47	34.5	Middleton and Gatesy 2000
Oceanodroma leucorhoa	15.5	34.5	24	Middleton and Gatesy 2000
Oceanodroma leucorhoa	17	35	26	Middleton and Gatesy 2000
Octphaps lophotes	35.3	48	27.7	Middleton and Gatesy 2000
Odontophorus guttatus	50.3	70.3	45	Middleton and Gatesy 2000
Odontophorus guttatus	47.1	67	42.7	Middleton and Gatesy 2000
Omnivoropteryx_sinousaorum	61	64.3	35	Benson and Choinier 2013
Opisthocomus hoazin	62.8	86.7	141	Middleton and Gatesy 2000
Opisthocomus hoazin	64.6	89.1	168	Middleton and Gatesy 2000
Opisthocomus hoazin	68	90	53.5	Middleton and Gatesy 2000
Ornithomimus edmontonicus	435	475	310	Middleton and Gatesy 2000
Ornithomimus_edmontonicus	432	516	372	Benson and Choinier 2013
Ornithomimus_edmontonicus	435	456	310	Benson and Choinier 2013
Ortalis vetula	65.5	95	62	Middleton and Gatesy 2000
Otus asio	41	57.5	44	Middleton and Gatesy 2000
Otus asio	41.5	57.5	56	Middleton and Gatesy 2000
Oviraptorid - undescribed	192	225	107	Middleton and Gatesy 2000
Oxyura australis	46	73	37	Middleton and Gatesy 2000
Pachyornis elephantopus	329	574	242	Middleton and Gatesy 2000
Pachyornis elephantopus	320	525	225	Middleton and Gatesy 2000
Pachyornis elephantopus	308.9	542.9	230.6	Middleton and Gatesy 2000
Pachyornis elephantopus	295	485	210	Middleton and Gatesy 2000
Pachyornis mappini	206.3	365.5	156.3	Middleton and Gatesy 2000
Pachyornis mappini	203	336	156	Middleton and Gatesy 2000
Pachyornis oweni	143	243	113	Middleton and Gatesy 2000
Pachyornis septentrionalis	174.1	291.7	133	Middleton and Gatesy 2000
Palaeortyx brevipes	35.6	56.8	28	Middleton and Gatesy 2000
Palaeortyx gallica	41.4	59.7	30.6	Middleton and Gatesy 2000
Palaeotis weigelti	145	268	200	Middleton and Gatesy 2000
Pandion haliaetus	77	122	53	Middleton and Gatesy 2000
Pandion haliaetus	79.6	126.6	54	Middleton and Gatesy 2000
Paraortyx lorteti	41.9	52	33.5	Middleton and Gatesy 2000
Paraprotopteryx_gracilis	22.2	26.3	15.7	Benson and Choinier 2013
Paraptenodytes antarcticus	115.9	178	53.4	Middleton and Gatesy 2000
Parus ater	11.8	22.2	16	Middleton and Gatesy 2000

Parus cristatus	12.8	23.9	17.9	Middleton and Gatesy 2000
Parus montanus	12.9	23.8	16.6	Middleton and Gatesy 2000
Parvicursor remotus	53	76	58	Dececchi and Larson 2013
Parvicursor_remotus	52.6	73	56	Benson and Choinier 2013
Patagona gigas	13.7	20.9	7.4	Middleton and Gatesy 2000
Patagona gigas	16	23.2	8.8	Middleton and Gatesy 2000
Patagopteryx_deferrariisi	100	131.5	51	Benson and Choinier 2013
Pavo cristatus	109	202	137	Middleton and Gatesy 2000
Pavo cristatus	107	193	139	Middleton and Gatesy 2000
Pavo cristatus	105	175	116	Middleton and Gatesy 2000
Pelecanoides urinatrix	24.8	47	31	Middleton and Gatesy 2000
Pelecanus erythrorhnchos	108.4	183	126.4	Middleton and Gatesy 2000
Pelecanus erythrorhnchos	119	181	121	Middleton and Gatesy 2000
Pelecanus occidentalis	88.1	119.8	78.5	Middleton and Gatesy 2000
Pelecanus occidentalis	90.8	122.1	80.2	Middleton and Gatesy 2000
Penelope purpascens	95	137	83	Middleton and Gatesy 2000
Penelopina nigra	108	163	107	Middleton and Gatesy 2000
Pengornis_houi	48	48.4	25.5	Benson and Choinier 2013
Perdix dauurica	0.337	0.413	0.25	Middleton and Gatesy 2000
Perdix dauurica	0.333	0.417	0.25	Middleton and Gatesy 2000
Perdix perdix	0.332	0.417	0.251	Middleton and Gatesy 2000
Perdix perdix	0.331	0.417	0.25	Middleton and Gatesy 2000
Pernis apivorus	61	90	55	Middleton and Gatesy 2000
Phaethon lepturus	29.1	43.8	22	Middleton and Gatesy 2000
Phaethon lepturus	30.5	46.1	22.2	Middleton and Gatesy 2000
Phalacoboenus australis	80	108	83	Middleton and Gatesy 2000
Phalacrocorax auritus	60.9	98.5	60.6	Middleton and Gatesy 2000
Phalacrocorax auritus	56.9	101.3	60.1	Middleton and Gatesy 2000
Phalacrocorax bougainvilli	56.5	107.5	60.7	Middleton and Gatesy 2000
Phalacrocorax carbo	61.7	105.7	65	Middleton and Gatesy 2000
Phalacrocorax carbo	66.7	123.2	69.1	Middleton and Gatesy 2000
Phalacrocorax carbo	59.1	110	64	Middleton and Gatesy 2000
Phalacrocorax urile	64.2	107.4	57	Middleton and Gatesy 2000
Phalaropus fulicarius	19.3	37.4	21.8	Middleton and Gatesy 2000
Phalaropus lobatus	19.7	38.3	29.8	Middleton and Gatesy 2000
Phalaropus lobatus	15.9	32.1	21.1	Middleton and Gatesy 2000
Phasianus colchicus	0.309	0.414	0.277	Middleton and Gatesy 2000
Phasianus colchicus	0.311	0.413	0.276	Middleton and Gatesy 2000
Phoebetria fusca	97	165	93	Middleton and Gatesy 2000
Phoebetria palpebrata	68	136	78	Middleton and Gatesy 2000
Phoenicopterus antiquorum	90.8	367	351	Middleton and Gatesy 2000
Phoenicopterus antiquorum	85.5	286	269	Middleton and Gatesy 2000
Phoenicopterus ruber	0.11	0.45	0.44	Middleton and Gatesy 2000

Phoenicopterus ruber	85.6	344	327	Middleton and Gatesy 2000
Phoenicopterus ruber	94.9	361	340	Middleton and Gatesy 2000
Phoenicopterus ruber	83	284	262	Middleton and Gatesy 2000
Phoenicopterus ruber	90	352	313	Middleton and Gatesy 2000
Phoenicopterus ruber	78	290	264	Middleton and Gatesy 2000
Phoenicopterus ruber	89	335	321	Middleton and Gatesy 2000
Phoenicopterus ruber	88	347	329	Middleton and Gatesy 2000
Piatnitzkysaurus floresi	552	492	290	Dececchi and Larson 2013
Piatnitzkysaurus_floresi	552	492	290	Benson and Choinier 2013
Pilherodias pileatus	49.5	78.2	52.5	Middleton and Gatesy 2000
Pionus aterrionus	37.8	50	17.4	Middleton and Gatesy 2000
Pionus aterrionus	37.6	49.1	17.1	Middleton and Gatesy 2000
Pitangus sulphuratus	24.1	39.7	26.9	Middleton and Gatesy 2000
Pitta erythrogaster	30.3	52.2	42.4	Middleton and Gatesy 2000
Pityriasis gymnocephala	33	48	33.1	Middleton and Gatesy 2000
Platalea leucoroidia	85	195	149	Middleton and Gatesy 2000
Plautus alle	27.8	46.2	20.1	Middleton and Gatesy 2000
Plautus alle	27.7	44.5	21.5	Middleton and Gatesy 2000
Plautus alle	28.8	45.9	20.9	Middleton and Gatesy 2000
Plautus impennes	71.2	130.3	50	Middleton and Gatesy 2000
Plautus impennes	75.8	125.9	56.4	Middleton and Gatesy 2000
Plecoplerus gambensis	96.6	173	112.8	Middleton and Gatesy 2000
Plegadis falcinellus	59	133	101	Middleton and Gatesy 2000
Plegadis falcinellus	54	136	97	Middleton and Gatesy 2000
Plegadis sp.	53	129	101	Middleton and Gatesy 2000
Podargus ocellatus	47.6	76.1	40.7	Middleton and Gatesy 2000
Podiceps auritus	33.6	77	46.9	Middleton and Gatesy 2000
Podiceps auritus	31.4	70.3	44.5	Middleton and Gatesy 2000
Podiceps auritus	30.8	70.7	43.3	Middleton and Gatesy 2000
Podiceps auritus	32.5	73.3	46.1	Middleton and Gatesy 2000
Podiceps auritus	33.2	77.1	48.4	Middleton and Gatesy 2000
Podiceps caspicus	31.7	66.6	41.7	Middleton and Gatesy 2000
Podiceps caspicus	30.3	64.3	38.9	Middleton and Gatesy 2000
Podiceps caspicus	29.8	63.9	40.8	Middleton and Gatesy 2000
Podiceps grisegena	46	107.5	61.9	Middleton and Gatesy 2000
Podilymbus podiceps	41.8	75.3	43.9	Middleton and Gatesy 2000
Podilymbus podiceps	36.2	63.2	36.9	Middleton and Gatesy 2000
Podilymbus podiceps	37.1	63.1	37.5	Middleton and Gatesy 2000
Podilymbus podiceps	41.1	71.6	41.9	Middleton and Gatesy 2000
Podilymbus podiceps	36.6	64.8	37.4	Middleton and Gatesy 2000
Podilymbus podiceps	40.4	72.7	41.6	Middleton and Gatesy 2000
Polyborus plancus	65	106	89	Middleton and Gatesy 2000
Polyborus plancus	67	104	88	Middleton and Gatesy 2000

Porphyrio porphyrio	72.9	134.4	68.2	Middleton and Gatesy 2000
Probisciger aterrionus	62	91.4	27.4	Middleton and Gatesy 2000
Probisciger aterrionus	58.2	81.4	26.5	Middleton and Gatesy 2000
Procompsognathus triassicus	93	113	69	Middleton and Gatesy 2000
Procompsognathus_triassicus	96	110.4	69.8	Benson and Choinier 2013
Progne subis	18.4	30.2	16.4	Middleton and Gatesy 2000
Protarchaeopteryx robusta	147	188	115	Dececchi and Larson 2013
Protarchaeopteryx_robusta	122	160	85	Benson and Choinier 2013
Protopteryx_fengningensis	20	32	17	Benson and Choinier 2013
Pteroglossus aracari	58.7	89	53.7	Middleton and Gatesy 2000
Pulsatrix perspicata	64	98	34	Middleton and Gatesy 2000
Pyrocephalus rubinus	13.1	21.3	16.3	Middleton and Gatesy 2000
Qiliania_graffini	24.3	30.9	20.3	Benson and Choinier 2013
Rahonavis ostromi	88	120	48	Dececchi and Larson 2013
Rahonavis_ostromi	86.9	118.8	47.8	Benson and Choinier 2013
Ramphastos toco	58.7	89	53.7	Middleton and Gatesy 2000
Rapaxavis_pani	19	23.5	12.5	Benson and Choinier 2013
Raptorrex	338	397	266	Dececchi and Larson 2013
Recurvirostra americana	36.8	108	90.7	Middleton and Gatesy 2000
Recurvirostra americana	38.3	120.3	86.7	Middleton and Gatesy 2000
Recurvirostra americana	36.6	107.4	82.7	Middleton and Gatesy 2000
Recurvirostra americana	40.1	115.1	97.9	Middleton and Gatesy 2000
Recurvirostra americana	37.2	106.6	91.1	Middleton and Gatesy 2000
Recurvirostra americana	38.5	111.7	94.2	Middleton and Gatesy 2000
Regulus regulus	9.7	21.2	17.1	Middleton and Gatesy 2000
Rhea americana	210	318	325	Middleton and Gatesy 2000
Rhea americana	159	278	284	Middleton and Gatesy 2000
Rhea americana	83	134	119	Middleton and Gatesy 2000
Rhea americana	215	325	320	Middleton and Gatesy 2000
Rhea americana	187	278	285	Middleton and Gatesy 2000
Rhea americana	195	329	306	Middleton and Gatesy 2000
Rhea americana	206	346	332	Middleton and Gatesy 2000
Rhea americana	210	330	320	Middleton and Gatesy 2000
Rhea americana	110	163	147	Middleton and Gatesy 2000
Rhynchotus rufescens	72.6	98.5	65	Middleton and Gatesy 2000
Rhynchotus rufescens	70	95	59	Middleton and Gatesy 2000
Rissa tridactyla	35	64	32	Middleton and Gatesy 2000
Rupicola rupicola	36.8	56.4	35.5	Middleton and Gatesy 2000
Rynchops nigra	34	55	30	Middleton and Gatesy 2000
Sagittarius serpentarius	100	283	272	Middleton and Gatesy 2000
Sagittarius serpentarius	107	270	258	Middleton and Gatesy 2000
Sandcoleus copiosus	36.5	50.9	28.1	Middleton and Gatesy 2000
Sapeornis angustis	58.3	68.5	33.1	Dececchi and Larson 2013

Sapeornis chaoyangensis	74.4	81.7	42	Dececchi and Larson 2013
Sapeornis_chaoyangensis	79	81.6	44	Benson and Choinier 2013
Sarcorhamphus papa	97	161	93	Middleton and Gatesy 2000
Sarcorhamphus papa	100	165	99	Middleton and Gatesy 2000
Saurophaganax maximus	1135	907	470	Dececchi and Larson 2013
Saurornithoides mongoliensis	198	243	139	Middleton and Gatesy 2000
Saurornitholestes langstoni	225	257	113	Dececchi and Larson 2013
Saurornitholestes_langstoni	212	285	117	Benson and Choinier 2013
Sayornis phoebe	14.4	25.6	18.2	Middleton and Gatesy 2000
Scansoriopteryx_heilmanni	16.5	19.3	12	Benson and Choinier 2013
Scelorchilus albicollis	27.7	46.7	37.8	Middleton and Gatesy 2000
Schizooura_lii	45	59.5	35	Benson and Choinier 2013
Segisaurus halli	145	160	99	Middleton and Gatesy 2000
Segnosaurus galbinensis	840	860	274	Dececchi and Larson 2013
Segnosaurus_galbinensis	840	860	274	Benson and Choinier 2013
Shanweiniao_cooperorum	17.6	21.8	11.8	Benson and Choinier 2013
Shenzhouraptor_sinensis	55.4	68.3	34.6	Benson and Choinier 2013
Similicaudipteryx	140	182	101	Dececchi and Larson 2013
Similicaudipteryx	38	48.6	29.1	Dececchi and Larson 2013
Similicaudipteryx yixianensis	220	240	183	Dececchi and Larson 2013
Similicaudipteryx_yixianensis	216	240	183	Benson and Choinier 2013
Sinocalliopteryx_gigas	250	280	160	Benson and Choinier 2013
Sinornis santensis	21	26	15	Dececchi and Larson 2013
Sinornis_santensis	21	25	14.6	Benson and Choinier 2013
Sinornithoides youngi	140	198	111	Middleton and Gatesy 2000
Sinornithoides youngi	140	191	111	Dececchi and Larson 2013
Sinornithoides_youngi	140	191	111	Benson and Choinier 2013
Sinornithomimus dongi	323	347	213	Dececchi and Larson 2013
Sinornithomimus_dongi	323	335	213	Benson and Choinier 2013
Sinornithosaurus	109.8	131.9	88.2	Dececchi and Larson 2013
Sinosauropteryx prima	86	100	64	Dececchi and Larson 2013
Sinosauropteryx prima	108	152	96	Dececchi and Larson 2013
Sinosauropteryx_prima	86.4	97	65	Benson and Choinier 2013
Sinovenator changii	118	154	85	Dececchi and Larson 2013
Sinraptor dongi	876	769	410	Middleton and Gatesy 2000
Sinraptor dongi	876	776	410	Dececchi and Larson 2013
Sinraptor_dongi	876	776	410	Benson and Choinier 2013
Sinusonasus_magnodens	141	179	106	Benson and Choinier 2013
Sitta carolinensis	15.7	24.5	18.3	Middleton and Gatesy 2000
Somateria mollissima	67	110	50	Middleton and Gatesy 2000
Somateria mollissima	66.8	113.3	55.5	Middleton and Gatesy 2000
Somateria mollissima	65.6	109	53.1	Middleton and Gatesy 2000
Speotyto cunicularia	40	69	36	Middleton and Gatesy 2000

Spheniscus demersus	70.4	101.1	28.5	Middleton and Gatesy 2000
Spheniscus humboldti	75.9	113.2	32.1	Middleton and Gatesy 2000
Spheniscus humboldti	77.9	112.7	32.3	Middleton and Gatesy 2000
Spheniscus humboldti	83.2	119.7	34.7	Middleton and Gatesy 2000
Spheniscus mendiculus	56.3	83.7	22.9	Middleton and Gatesy 2000
Spheniscus sp.	70.5	104	32.3	Middleton and Gatesy 2000
Spizaetus ornatus	88	124	90	Middleton and Gatesy 2000
Steatornis caripensis	39	45.3	19.8	Middleton and Gatesy 2000
Stercorarius parasiticus	36.4	66.3	42.7	Middleton and Gatesy 2000
Sterna fuscata	27	44	24	Middleton and Gatesy 2000
Sterna hirundo	24	40	20	Middleton and Gatesy 2000
Sterna striata	27	43	20	Middleton and Gatesy 2000
Stictocarbo magellanicus	54.7	93.9	51.3	Middleton and Gatesy 2000
Stictocarbo magellanicus	53.3	91.2	51.1	Middleton and Gatesy 2000
Strepera graculina	44.7	78.3	52.5	Middleton and Gatesy 2000
Strigops habroptilus	85.6	117.9	51.1	Middleton and Gatesy 2000
Strix varia	77	113	51	Middleton and Gatesy 2000
Strix varia	69	98	52	Middleton and Gatesy 2000
Struthio camelus	230	410	398	Middleton and Gatesy 2000
Struthio camelus	320	545	483	Middleton and Gatesy 2000
Struthio camelus	317	567	493	Middleton and Gatesy 2000
Struthio camelus	285	495	430	Middleton and Gatesy 2000
Struthio camelus	266	494	437	Middleton and Gatesy 2000
Struthio camelus	278	490	432	Middleton and Gatesy 2000
Struthio camelus	314	550	474	Middleton and Gatesy 2000
Struthio camelus	308	527	455	Middleton and Gatesy 2000
Struthio camelus	305	511	447	Middleton and Gatesy 2000
Struthio camelus	293	480	461	Middleton and Gatesy 2000
Struthio camelus	273	497	410	Middleton and Gatesy 2000
Struthio camelus	277	490	420	Middleton and Gatesy 2000
Struthiomimus altus	513	560	385	Middleton and Gatesy 2000
Struthiomimus altus	502	556	398	Middleton and Gatesy 2000
Struthiomimus altus	480	535	365	Middleton and Gatesy 2000
Struthiomimus altus	430	560	387	Middleton and Gatesy 2000
Struthiomimus altus	397	430	297	Middleton and Gatesy 2000
Struthiomimus altus	480	535	365	Dececchi and Larson 2013
Struthiomimus_altus	480	514	365	Benson and Choinier 2013
Struthiomimus_altus	480	521.5	365	Benson and Choinier 2013
Sula sp.	56.4	79.3	51.1	Middleton and Gatesy 2000
Sula variegata	54.9	78.5	46.6	Middleton and Gatesy 2000
Syntarsus sp.	208	223	132	Middleton and Gatesy 2000
Szechuanosaurus campi	364	360	200	Middleton and Gatesy 2000
Szechuanosaurus campi	585	580	225	Dececchi and Larson 2013

Tachyeres brachyplerus	76	120	61	Middleton and Gatesy 2000
Tadorna tadorna	57	102	68	Middleton and Gatesy 2000
Tanycolagreus topwilsoni	356	387	216	Dececchi and Larson 2013
Tanycolagreus_topwilsoni	356	382	216	Benson and Choinier 2013
Taraba major	28.4	45.6	35.9	Middleton and Gatesy 2000
Tarbosaurus bataar	560	605	420	Middleton and Gatesy 2000
Tarbosaurus bataar	970	880	540	Middleton and Gatesy 2000
Tarbosaurus bataar	700	700	445	Middleton and Gatesy 2000
Tarbosaurus bataar	580	590	410	Middleton and Gatesy 2000
Tarbosaurus_bataar	940	945	535	Benson and Choinier 2013
Tetrao urogalloides	0.339	0.433	0.228	Middleton and Gatesy 2000
Tetrao urogalloides	0.335	0.435	0.23	Middleton and Gatesy 2000
Tetrao urogallus	80.9	106.7	55	Middleton and Gatesy 2000
Tetrao urogallus	0.348	0.428	0.224	Middleton and Gatesy 2000
Tetrao urogallus	0.344	0.43	0.226	Middleton and Gatesy 2000
Tetraogallus altaicus	0.344	0.439	0.228	Middleton and Gatesy 2000
Tetraogallus altaicus	0.337	0.438	0.225	Middleton and Gatesy 2000
Tetraogallus caucasicus	0.336	0.441	0.223	Middleton and Gatesy 2000
Tetraogallus himalayensis	0.332	0.443	0.225	Middleton and Gatesy 2000
Tetraogallus himalayensis	0.331	0.442	0.227	Middleton and Gatesy 2000
Tetrastes bonasia	0.334	0.44	0.226	Middleton and Gatesy 2000
Tetrastes bonasia	0.333	0.437	0.23	Middleton and Gatesy 2000
Thallaseus maximus	38	64	33	Middleton and Gatesy 2000
Theristicus melanopis	60	112	75	Middleton and Gatesy 2000
Theristicus melanopis	65	140	99	Middleton and Gatesy 2000
Tianyuraptor ostromi	200	260	141	Dececchi and Larson 2013
Tianyuraptor_ostromi	200	255	150	Benson and Choinier 2013
Tigrisoma lineatum	70.9	122.4	92.6	Middleton and Gatesy 2000
Tinamus major	65	98.2	69	Middleton and Gatesy 2000
Tinamus tao	70	108	70.8	Middleton and Gatesy 2000
Toxostoma rufum	27.9	47.6	34.4	Middleton and Gatesy 2000
Trichoglossus ornatus	27.4	40.3	15.2	Middleton and Gatesy 2000
Trichoglossus ornatus	28.1	37.4	15.8	Middleton and Gatesy 2000
Trichoglossus ornatus	28.5	39.7	15.3	Middleton and Gatesy 2000
Tringa flavipes	25.9	64.2	53.7	Middleton and Gatesy 2000
Tringa flavipes	27.7	64.6	52.1	Middleton and Gatesy 2000
Tringa flavipes	26.7	63.5	50.1	Middleton and Gatesy 2000
Trogon massena	27.5	36	16.2	Middleton and Gatesy 2000
Troodon formosus	310	350	220	Dececchi and Larson 2013
Troodon_formosus	317	361	206.5	Benson and Choinier 2013
Turdus migratorius	25.5	42	30.4	Middleton and Gatesy 2000
Tympanuchus cupido	62.3	82.1	45.7	Middleton and Gatesy 2000
Tyrannosaurus rex	1340	1180	698	Middleton and Gatesy 2000

Tyrannosaurus rex	1300	1140	684	Middleton and Gatesy 2000
Tyrannosaurus rex	1143	1118	593	Middleton and Gatesy 2000
Tyrannosaurus rex	1350	1110	671	Dececchi and Larson 2013
Tyrannosaurus_rex	1321	1185	610	Benson and Choinier 2013
Tyrannus verticalis	18.3	29	17.9	Middleton and Gatesy 2000
Tyto alba	52	84	82	Middleton and Gatesy 2000
Tyto alba	50	90	197	Middleton and Gatesy 2000
Uria aalge	47.4	87.5	36.1	Middleton and Gatesy 2000
Uria aalge	48	86	38.1	Middleton and Gatesy 2000
Uria aalge	49	86.9	37.2	Middleton and Gatesy 2000
Uria lomvia	46.6	82.6	36.6	Middleton and Gatesy 2000
Uria lomvia	47.8	82.9	36	Middleton and Gatesy 2000
Uria lomvia	48	86.8	37.9	Middleton and Gatesy 2000
Vanellus chilensis	37.8	98.3	82.6	Middleton and Gatesy 2000
Vanellus chilensis	40.6	92.2	72.8	Middleton and Gatesy 2000
Velociraptor mongoliensis	238	255	99	Dececchi and Larson 2013
Velociraptor_mongoliensis	187	203	99.4	Benson and Choinier 2013
Vescornis_hebeiensis	23	27.8	15.4	Benson and Choinier 2013
Vorona_berivotrensis	94	160	59	Benson and Choinier 2013
Vultur gryphus	138	220	121	Middleton and Gatesy 2000
Vultur gryphus	153.1	243	130.1	Middleton and Gatesy 2000
Xenorhynchus asiaticus	102	350	301	Middleton and Gatesy 2000
Xixianykus zhangi	70	91	68	Dececchi and Larson 2013
Yanornis martini	26.5	35.1	19.5	Dececchi and Larson 2013
Yanornis_martini	52	75	37	Benson and Choinier 2013
Yixianornis grabaui	41	52.8	27	Dececchi and Larson 2013
Yixianornis_grabaui	41	50	25	Benson and Choinier 2013
Zemaidura macrocoura	26.2	36.2	19.9	Middleton and Gatesy 2000
Zhongjianornis yangi	48	71	29	Dececchi and Larson 2013
Zhongjianornis_yangi	48	68	28	Benson and Choinier 2013
Zhongornis	15.3	20.5	10.6	Dececchi and Larson 2013
Zhongornis_haoae	15.3	20.5	9.9	Benson and Choinier 2013

APPENDIX B

Phylogeny Sources

Benson and Choinier 2013
Bertelli et al. 2002
Chesser et al. 2010
Cotgrave and Clayton 1994
Crowe et al. 2006
Dececchi and Larsson 2013
Donne-Gousse et al. 2002
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Martinez et al. 2011
McCracken and Sheldon 1998
Pointer and Mundy 2008
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Ruokonen et al. 2000
Shapiro et al. 2002
Sheldon 1987
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Shibusawa et al. 2004
Silkas 1997
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APPENDIX C

Molecular Dates and Fossil Occurrences Used to Date Tree Nodes

Contents:

a. Molecular Dates
b. Fossil Occurrences

a. Molecular Dates

Clade	Min BEAST date (mya)	Max BEAST date (mya)	Source
Neognaths-Paleognaths	133.2 + 8.1	133.2 - 8.1	Brown et al. 2012
Paleognaths	105.9 + 11.7	105.9 - 11.7	Brown et al. 2012
Galloanserae	110.4 + 7.8	110.4 - 7.8	Brown et al. 2012
Galloanserae-Neoaves	126.0 + 7.1	126.0 - 7.1	Brown et al. 2012
Neoaves	118.5 + 6.8	118.5 - 6.8	Brown et al. 2012
Ratites	91.5 + 12.0	91.5 - 12.0	Brown et al. 2012
Galliformes	99.0 + 8.4	99.0 - 8.4	Brown et al. 2012
Anseriformes	100.5 + 8.3	100.5 - 8.3	Brown et al. 2012
Charadriiformes	81.7 + 6.3	81.7 - 6.3	Brown et al. 2012
Passeriformes	106.6 + 7.2	106.6 - 7.2	Brown et al. 2012
Piciformes	93.6 + 6.8	93.6 - 6.8	Brown et al. 2012
Procellariiformes	74.7 + 7.3	74.7 - 7.3	Brown et al. 2012
Cuculiformes	74.1 + 8.6	74.1 - 8.6	Brown et al. 2012
Strigiformes	84.2 + 9.1	84.2 - 9.1	Brown et al. 2012
Apodiformes	80.5 + 9.9	80.5 - 9.9	Brown et al. 2012
Spilt Suboscines vs. Oscines	58	84	Ericson et al. 2014
Split OW vs. NW Suboscines	50	77	Ericson et al. 2014
Oscines	46	71	Ericson et al. 2014
Core Corvoidea	28	47	Ericson et al. 2014
Eupasseri	33	53	Ericson et al. 2014

b. Fossil Occurances

species	ageFO_max	ageFO_min	ageLO_max	ageLO_min
Accipiter_cooperii	4.9	1.8	0.126	0
Accipiter_gentilis	0.781	0.126	0.01882	0
Achillobator_giganticus	100.5	83.6	100.5	83.6
Acrocanthosaurus_atokensis	125	113	122.46	112.03
Aechmophorus_occidentalis	2.588	0.012	0.126	0.0117
Aegolius_funereus	0.126	0.0117	0.126	0.0117
Afrovenator_abakensis	174.1	145	174.1	145
Aix_sponsa	4.9	1.8	0.126	0.0117
Ajaia_ajaja	0.126	0.0117	0.126	0.0117

Ajancingenia_yanshini	83.6	66	83.6	66
Albertosaurus_sarcophagus	83.6	72.1	70.6	66
Alca_torda	11.62	7.246	0.126	0.0117
Alectrosaurus_olseni	93.9	83.6	93.9	83.6
Alethoalaornis_agitornis	125	113	125	113
Allosaurus_fragilis	157.3	152.1	150.2	145
Alxasaurus_elesitaiensis	125	113	125	113
Anas_clypeata	5.333	3.6	0.126	0.0117
Anas_platyrhynchos	5.333	3.6	0.0117	0
Anas_rubripes	2.588	0.0117	0.126	0.0117
Anchiornis_huxleyi	167.7	150.8	167.7	150.8
Anhinga_anhinga	0.3	0.012	0.126	0.0117
Anser_caerulescens	0.126	0.0117	0.126	0.0117
Anser_fabalis	2.588	0.0117	2.588	0.0117
Apsaravis_ukhaana	83.6	72.1	83.6	72.1
Apteryx_australis	0.126	0.0117	0.126	0.0117
Apus_apus	0.781	0.126	0.781	0.126
Aquila_chrysaetos	3.2	2.588	0.01882	0
Aramus_guarauna	0.126	0.0117	0.126	0.0117
Archaeopteryx_lithographica	152.1	145	150.8	145
Archaeorhynchus_spathula	125.45	122.46	125.45	122.46
Archaeornithomimus_asiaticus	93.9	83.6	89.8	83.6
Ardea_cocoi	0.126	0.0117	0.126	0.0117
Ardea_herodias	0.3	0.012	0.126	0.0117
Asio_flammeus	2.588	0.781	0.0117	0
Asio_otus	2.588	0.0117	0.01882	0
Aucasaurus_garridoi	83.5	70.6	83.5	70.6
Australovenator_wintonensis	105.3	99.6	105.3	99.6
Austroraptor_cabazai	83.5	66	72.1	65.5
Avimimus_portentosus	83.6	72.1	83.5	65.5
Aythya_marila	1.8	0.3	1.8	0.3
Balaur_bondoc	72.1	66	72.1	66
Bambiraptor_feinbergi	85.8	72.1	83.6	70.6
Baptornis_advenus	89.8	86.3	89.8	83.6
Beishanlong_grandis	125	100.5	125	100.5
Bombycilla_cedrorum	0.126	0.0117	0.126	0.0117
Bonasa_umbellus	1.8	0.3	0.0261	0
Botaurus_lentiginosus	4.9	1.8	0.126	0.0117
Branta_canadensis	4.9	1.8	0.0261	0.0117
Branta_leucopsis	2.588	0.0117	2.588	0.0117
Bubo_virginianus	4.9	1.8	0.01882	0
Bucephala_albeola	5.333	3.6	0.126	0.0117
Buteo_jamaicensis	5.333	3.6	0.01207	0

Buteo_rufinus	0.781	0.126	0.781	0.126
Butorides_virescens	1.8	0.3	0.126	0.0117
Carnotaurus_sastrei	83.6	72.1	83.6	72.1
Casuarius_sp.	3.6	2.588	3.6	2.588
Cathartes_aura	2.588	0.0143	0.0117	0
Cathayornis_chabuensis	145	100.5	145	100.5
Cathayornis_yandica	129.4	113	125	113
Caudipteryx_zoui	130	122.46	130	122.46
Cepphus_grylle	0.126	0.0117	0.126	0.0117
Ceratosaurus_nasicornis	157.3	152.1	150.2	145
Cerorhinca_monocerata	0.126	0.0117	0.126	0.0117
Chaetura_pelagica	0.126	0.0117	0.126	0.0117
Changchengornis_hengdaoziensis	145	125	145	125
Chascacocolius_oscitans	56	47.8	56	47.8
Chendytes_lawi	2.588	0.012	0.126	0.0117
Chilantaisaurus_tashuikouensis	93.9	89.8	93.9	89.8
Chirostenotes_pergracilis	83.6	72.1	83.5	70.6
Circus_cyaneus	2.588	0.781	0.126	0.0117
Citipati_osmolskae	83.6	72.1	83.6	66
Cnemiornis_calcitrans	0.126	0.0117	0.126	0
Coccyzus_americanus	4.9	1.8	0.126	0.0117
Coelophysis_bauri	228	208.5	208.5	201.3
Coelophysis_kayentakatae	199.3	182.7	199.3	182.7
Coelophysis_rhodesiensis	237	201.3	201.3	190.8
Coelurus_fragilis	157.3	152.1	157.3	145
Colaptes_cafer	2.588	0.0143	0.0261	0.0117
Colinus_virginianus	4.9	1.8	0.02987	0
Columba_livia	5.333	2.588	0.126	0.0117
Columbina_talpacoti	0.126	0.0117	0.126	0.0117
Compsognathus_longipes	152.1	145	150.8	145
Concavenator_corcovatus	130	125.45	130	125.45
Concornis_lacustris	130	125.45	130	125.45
Confuciusornis_dui	130	122.46	130	122.46
Confuciusornis_feducciai	130	122.46	130	122.46
Confuciusornis_jianchangensis	125	113	125	113
Confuciusornis_sanctus	130	122.46	130	122.46
Confuciusornis_suniae	130	122.46	130	122.46
Coragyps_atratus	4.9	1.8	0.126	0.0117
Coturnix_coturnix	2.588	0.781	0.126	0.0117
Cygnus_atratus	0.126	0.0117	0.126	0.0117
Dalianraptor_cuhe	145	100.5	145	100.5
Dalingheornis_liweii	129.4	125	129.4	125
Dapingfangornis_sentisorhinus	125	113	125	113

Daspletosaurus_torosus	83.6	72.1	83.5	66
Deinocheirus_mirificus	70.6	66	70.6	66
Deinonychus_antirrhopus	125	113	113	100.5
Deltadromeus_agilis	99.6	93.5	99.6	93.5
Dendrocygna_autumnalis	2.588	0.0117	0.126	0
Dilong_paradoxus	130	122.46	130	122.46
Dilophosaurus_sinensis	201.3	190.8	201.3	190.8
Dilophosaurus_wetherilli	199.3	182.7	199.3	182.7
Dinornis_giganteus	0.126	0.0117	0.126	0.0117
Dromaius_novaehollandiae	5.333	0.781	2.588	0.0117
Dryocopus_pileatus	0.126	0.0117	0.126	0.0117
Dryptosaurus_aquilunguis	70.6	66	70.6	66
Ectopistes_migratorius	5.333	3.6	0.02987	0
Egretta_alba	2.588	0	2.588	0
Egretta_caerulea	0.126	0.0117	0.126	0.0117
Egretta_thula	0.126	0.0117	0.126	0.0117
Elaphrosaurus_bambergi	155.7	150.8	99.6	93.5
Emeus_crassus	0.126	0.0117	0.0117	0
Eoabelisaurus_mefi	174.1	168.3	174.1	168.3
Eoalulavis_hoyasi	130	125.45	130	125.45
Eocathayornis_walkeri	125	113	125	113
Eoconfuciusornis_zhengi	132.9	125	132.9	125
Eodromaeus_murphi	237	228	237	228
Eoenantiornis_buhleri	129.4	122.46	129.4	122.46
Eoraptor_lunensis	231.5	229	231.5	229
Epidendrosaurus_ningchengensis	166.1	157.3	166.1	157.3
Epidexipteryx_hui	166.1	157.3	166.1	157.3
Eremophila_alpestris	2.588	0.0117	0.126	0.0117
Eudyptula_minor	0.126	0.0117	0.0117	0
Euryapteryx_geranoides	0.126	0.0117	0.126	0
Eustreptospondylus_oxoniensis	164.7	161.2	164.7	161.2
Falcarius_utahensis	129.4	125	129.4	125
Falco_sparverius	4.9	1.8	0.0117	0
Fulmarus_glacialis	0.3	0.012	0.126	0.0117
Gallimimus_bullatus	83.6	66	83.6	66
Gallirallus_australis	0.126	0.0117	0.126	0.0117
Gallus_gallus	0.0117	0	0.0117	0
Gansus_yumenensis	125	113	125	113
Garudimimus_brevipes	100.5	83.6	100.5	83.6
Gasosaurus_constructus	170.3	163.5	170.3	163.5
Gavia_immer	2.588	0.012	0.0117	0
Gavia_sp.	20.43	15.97	0.126	0.0117
Gavia_stellata	0.3	0.012	0.126	0.0117

Gigantoraptor_erlianensis	89.3	66	89.3	66
Gobipteryx_minuta	83.6	72.1	83.5	66
Gorgosaurus_libratus	83.6	72.1	83.5	70.6
Graciliraptor_lujiatunensis	125.45	122.46	125.45	122.46
Grus_antigone	5.333	3.6	2.588	0.0117
Grus_canadensis	4.9	1.8	0.01882	0
Guaibasaurus_candelariensis	228	208.5	228	208.5
Guanlong_wucaii	163.5	157.3	163.5	157.3
Gymnogyps_californianus	2.588	0.0143	0.0261	0.0117
Gypaetus_barbatus	2.588	0.0117	2.588	0.0117
Haliaeetus_leucocephalus	0.126	0.0117	0.0117	0
Haplocheirus_sollers	161.2	158.7	161.2	158.7
Harpymimus_okladnikovi	109	99.6	109	99.6
Herrerasaurus_ischigualastensis	237	229	228	201.3
Hesperornis_regalis	85.8	83.5	83.5	70.6
Hexing_qingyi	140.2	125.45	140.2	125.45
Heyuannia_huangi	72.1	66	72.1	66
Hirundo_rustica	2.588	0.781	2.588	0.0117
Hongshanornis_longicresta	129.4	125	129.4	113
Huaxiagnathus_orientalis	130	122.46	130	122.46
Huoshanornis_huji	125	113	125	113
Iberomesornis_romerali	130	125.45	130	125.45
Ichthyornis_dispar	89.8	85.8	83.5	70.6
Jacana_spinosa	0.3	0.012	0.126	0.0117
Jeholornis_palmapenis	125.45	122.46	125.45	122.46
Jeholornis_prima	125	113	125	113
Jianchangornis_microdonta	125.45	122.46	125.45	122.46
Jibeinia_luanhera	129.4	113	129.4	113
Jixiangornis_orientalis	125.45	122.46	125.45	122.46
Juravenator_starki	155.7	150.8	155.7	150.8
Khaan_mckennai	83.6	66	83.6	66
Larus_argentatus	5.333	3.6	5.333	3.6
Larus_atricilla	5.333	3.6	0.126	0.0117
Larus_pipixcan	2.588	0.0117	0.126	0.0117
Liaoningornis_longidigitris	125.45	122.46	125.45	122.46
Liliensternus_liliensterni	228	208.5	228	208.5
Limosa_fedoa	2.588	0.0117	0.126	0.0117
Limusaurus_inextricabilis	163.5	157.3	163.5	157.3
Linhenykus_monodactylus	83.6	72.1	83.6	72.1
Linheraptor_exquisitus	83.6	72.1	83.6	72.1
Longchengornis_sanyanensis	125	113	125	113
Longicrusavis_houi	129.4	125	129.4	125
Longipteryx_chaoyangensis	125	113	125	113

Longirostravis_hani	125.45	122.46	125.45	122.46
Lophodytes_cucullatus	0.126	0.02987	0.02987	0.0117
Lophostropheus_airelensis	208.5	199.3	208.5	199.3
Mahakala_omnogovae	83.5	70.6	83.5	70.6
Majungasaurus_crenatissimus	72.1	66	72.1	66
Mancalla_cedrosensis	7.246	5.333	5.333	3.6
Masiakasaurus_knopfleri	72.1	66	72.1	66
Megaceryle_alcyon	0.126	0.0117	0.126	0.0117
Megadyptes_antipodes	0.126	0.0117	0.126	0.0117
Megalosaurus_bucklandii	170.3	168.3	125.45	122.46
Mei_long	139.8	129.4	125.45	122.46
Melanitta_fusca	0.126	0.0117	0.126	0.0117
Meleagris_gallopavo	2.588	0.3	0.0117	0
Mergus_australis	0.126	0.0117	0.126	0.0117
Mergus_merganser	4.9	1.8	0.126	0.0117
Mergus_serrator	5.333	3.6	0.126	0.0117
Microraptor_gui	125	113	125	113
Microraptor_zhaoianus	125	113	125	113
Mononykus_olecranus	72.1	66	72.1	66
Morus_bassanus	2.588	0.0117	0.0117	0
Mycteria_americana	0.126	0.0117	0.126	0.0117
Mycteria_ibis	2.588	0	2.588	0
Mycteria_sp.	23.03	15.97	23.03	15.97
Nedcolbertia_justinhoffmanni	129.4	125	129.4	125
Neimongosaurus_yangi	93.9	83.6	93.9	83.6
Nestor_meridionalis	0.126	0.0117	0.126	0.0117
Noguerornis_gonzalezi	129.4	125	129.4	125
Nothronychus_graffami	99.6	89.3	99.6	89.3
Nqwebasaurus_thwazi	145	132.9	145	132.9
Numenius_americanus	0.126	0.0117	0.126	0.0117
Numenius_arquata	2.588	0.0117	2.588	0.0117
Numida_meleagris	0.0117	0	0.0117	0
Nycticorax_sp.	33.9	28.1	33.9	28.1
Oceanites_oceanicus	0.0117	0	0.0117	0
Omnivoropteryx_sinousaorum	125	113	125	113
Ornitholestes_hermanni	157.3	145	157.3	145
Ornithomimus_edmontonicus	83.5	70.6	70.6	66
Otus_asio	4.9	1.8	0.0261	0
Oviraptor_philoceratops	83.5	70.6	83.5	70.6
Pachyornis_elephantopus	0.126	0.0117	0.0117	0
Palaeortyx_gallica	28.4	23.03	28.4	23.03
Palaeospheniscus_patagonicus	23.03	15.97	20.44	15.97
Palaeotis_weigelti	47.8	41.3	47.8	41.3

Pandion_haliaetus	2.588	0.0117	0.0042	0
Paraprotopteryx_gracilis	130	122.46	130	122.46
Paraptenodytes_antarcticus	23.03	20.44	15.97	11.608
Parvicursor_remotus	83.5	70.6	83.5	70.6
Patagopteryx_deferrariisi	86.3	83.6	86.3	83.6
Pelecanimimus_polyodon	130	125.45	130	125.45
Pelecanoides_urinatrix	0.126	0.0117	0.126	0.0117
Pelecanus_occidentalis	0.126	0.0117	0.126	0.0117
Pengornis_houi	125	113	125	113
Phaethon_lepturus	0.0117	0	0.0117	0
Phalacrocorax_auritus	2.588	0.3	0.126	0.0117
Phalacrocorax_carbo	2.588	0.126	0.781	0
Phalaropus_fulicarius	2.588	0.0117	2.588	0.0117
Phalaropus_lobatus	2.588	0.0117	2.588	0.0117
Phoenicopterus_antiquorum	2.588	0.0117	2.588	0.0117
Phoenicopterus_ruber	1.8	0.3	1.8	0.3
Piatnitzkysaurus_floresi	166.1	163.5	166.1	163.5
Plegadis_sp.	4.9	1.8	0.126	0.0117
Podiceps_auritus	15.97	13.6	0.126	0.0117
Podiceps_caspicus	0.126	0.0117	0.126	0.0117
Podilymbus_podiceps	4.9	2.588	0.0117	0
Procompsognathus_triassicus	215.56	212	215.56	212
Protarchaeopteryx_robusta	130	122.46	130	122.46
Protopteryx_fengningensis	130	122.46	130	122.46
Qiliania_graffini	125	113	125	113
Rahonavis_ostromi	72.1	66	72.1	66
Rapaxavis_pani	125	113	125	113
Recurvirostra_americana	0.126	0.0117	0.126	0.0117
Rhea_americana	0.126	0.0117	0.0117	0
Rissa_tridactyla	2.588	0.0117	0.126	0.0117
Sapeornis_chaoyangensis	125.45	122.46	125	113
Saurophaganax_maximus	155.7	145	155.7	145
Saurornithoides_mongoliensis	83.6	72.1	83.5	66
Saurornitholestes_langstoni	83.6	72.1	70.6	66
Sayornis_phoebe	0.126	0.0117	0.126	0.0117
Scansoriopteryx_heilmanni	129.4	125	129.4	125
Schizooura_lii	125.45	122.46	125.45	122.46
Scipionyx_samniticus	112.03	109	112.03	109
Segisaurus_halli	190.8	174.1	190.8	174.1
Shanweiniao_cooperorum	125.45	122.46	125.45	122.46
Shenqiornis_mengi	163.5	125	163.5	125
Shenzhouraptor_sinensis	125.45	122.46	125.45	122.46
Shuvuuia_deserti	83.6	70.6	83.5	66

Similicaudipteryx_yixianensis	125	113	125	113
Sinocalliopteryx_gigas	129.4	122.46	129.4	122.46
Sinornis_santensis	125	113	125	113
Sinornithoides_youngi	139.8	100.5	139.8	100.5
Sinornithomimus_dongi	93.9	89.8	93.9	89.8
Sinornithosaurus_haoiana	125.45	122.46	125.45	122.46
Sinornithosaurus_millenii	130	122.46	130	122.46
Sinosauropteryx_prima	130	122.46	130	122.46
Sinovenator_changii	125.45	123.2	123.2	122.46
Sinraptor_dongi	163.5	157.3	163.5	157.3
Sinusonasus_magnodens	125.45	122.46	125.45	122.46
Sitta_carolinensis	2.588	0.0117	2.588	0.0117
Somateria_mollissima	5.333	3.6	0.0117	0
Speotyto_cunicularia	4.9	1.8	0.126	0.0117
Spheniscus_demersus	0.781	0.126	0.126	0.0117
Spheniscus_humboldti	7.246	5.333	7.246	5.333
Spheniscus_sp.	23.03	10.2	5.333	2.588
Stercorarius_parasiticus	5.333	3.6	5.333	3.6
Sterna_maxima	5.333	3.6	5.333	3.6
Strix_varia	4.9	1.8	0.126	0.0117
Struthio_camelus	2.588	0.0117	0.0052	0
Struthiomimus_altus	83.6	72.1	72.1	66
Sula_sp.	20.44	15.97	5.333	3.6
Syntarsus_sp.	208.5	201.3	201.3	190.8
Tadorna_tadorna	2.588	0.0117	0.126	0.0117
Tanycolagreus_topwilsoni	157.3	152.1	157.3	145
Tarbosaurus_bataar	83.6	72.1	70.6	66
Teratornis_merriami	2.588	0.3	0.01882	0
Therizinosaurus_cheloniformis	72.1	66	72.1	66
Tianyuraptor_ostromi	129.4	125	129.4	125
Torvosaurus_tanneri	157.3	152.1	150.2	145
Toxostoma_rufum	1.8	0.3	0.126	0.0117
Troodon_formosus	85.8	72.1	68	66
Turdus_migratorius	0.126	0.0117	0.126	0
Tympanuchus_cupido	0.126	0.0117	0.126	0.0117
Tyrannosaurus_rex	83.5	70.6	70.6	66
Tyto_alba	4.9	1.8	0.0117	0
Uria_aalge	2.588	0.0117	0.0117	0
Velociraptor_mongoliensis	100.5	83.6	83.5	66
Vescornis_hebeiensis	129.4	113	129.4	113
Vorona_berivotrensis	72.1	66	72.1	66
Vultur_gryphus	2.588	0.781	0.126	0.0117
Xiaotingia_zhengi	167.7	150.8	167.7	150.8

Xixianykus_zhangi	89.3	83.6	89.3	83.6
Xuanhanosaurus_qilixiaensis	174.1	163.5	174.1	163.5
Yanornis_martini	125	113	125	113
Yixianornis_grabaui	125	113	125	113
Yixianosaurus_longimanus	130	122.46	130	122.46
Zhongjianornis_yangi	125.45	122.46	125.45	122.46
Zhongornis_haoae	125.45	122.46	125.45	122.46

APPENDIX D

Significance Values

Contents:

a. Test: Non-Flying Values are Greater than Flying Values

Forelimbs	p-values
h Evolutionary Rates	0.38
r Evolutionary Rates	0.52
cmc Evolutionary Rates	0
h/r Evolutionary Correlations	0.42
h/cmc Evolutionary Correlations	0.11
r/cmc Evolutionary Correlations	0.17

Hind Limbs	
f Evolutionary Rates	0
ti Evolutionary Rates	0.018
ta Evolutionary Rates	0.107
f/ti Evolutionary Correlations	0
f/ta Evolutionary Correlations	0
ti/ta Evolutionary Correlations	0

b. Test: Element 1 Values are Greater Than Element 2 Values

Forelimbs

Element 1	Element 2	Flying p-value	Non-Flying p-value
h Rates	r Rates	0.94	0.65
r Rates	cmc Rates	0	1
h Rates	cmc Rates	0	1
h/r Correlations	h/cmc Correlations	0	0.99
h/r Correlations	r/cmc Correlations	0	1
h/cmc Correlations	r/cmc Correlations	1	0.86

Hind Limbs

Element 1	Element 2	Flying p-value	Non-Flying p-value
f Rates	ti Rates	1	0.036
ti Rates	ta Rates	1	0.5
f Rates	ta Rates	1	0.232

f/ti Correlations	f/ta Correlations	0.125	0.286
f/ti Correlations	ti/ta Correlations	1	0.125
f/ta Correlations	ti/ta Correlations	1	0.054

APPENDIX E

Linear Measurements

Contents:

a. Adult
b. Embryonic

CH = Chicken, DU = Duck, CB = Cowbird
hum_l = humerus length, hum_w = humerus width, rad_l = radius length, rad_w = radius width, carp_l = carpometacarpus length, carp_w = carpometacarpus width, fem_l = femur length, fem_w = femur width, tib_l = tibiotarsus length, tib_w = tibiotarsus width, tar_l = tarsometatarsus length, tar_w = tarsometatarsus width

a. Adult

	hum_l	hum_w	rad_l	rad_w	carp_l	carp_w	fem_l	fem_w	tib_l	tib_w	tar_l	tar_w
CH01	91.68	22.24	79.75	8.89	43.97	8.13	99.56	24.72	144.14	23.79	94.59	19.79
CH02	89.14	21.12	77.85	9.78	44.99	8.25	102.3	23.12	144.65	23.52	94.17	19.69
CH03	98.5	23.27	84.47	10.24	46.21	9.19	110.82	26.11	157.12	25.67	99.11	20.05
CH04	85.62	20.88	76.35	9.54	42.48	8.81	100.66	24.42	142.08	24.03	96.36	17.26
CH05	94.59	23.89	85.11	9.79	47.05	9.27	106.93	26.82	150.7	24.99	102.45	20.38
CH07	88.88	21.52	79.67	8.92	43.9	8.5	100.18	24.21	138.35	22.01	92.37	18.37
CH08	96.83	22.69	83.66	8.83	46.55	8.86	108.61	24.42	151.78	21.95	100.44	18.15
CH09	90.33	21.78	80.43	10.24	44.44	9.45	103.95	24.57	148.62	21.74	97.04	19.74
CH10	89.44	21.83	77.03	9.51	42.82	9.79	100.87	24.62	142.75	21.72	93.78	18.52
CH11	87.38	20.88	75.7	8.96	43.15	9.1	99.67	24.19	143.02	22.54	94.2	18.23
CH12	87.48	21.46	76.51	9.09	44.75	8.44	98.05	24.77	141.16	24.07	96.19	19.79
CH13	86.7	20.81	76.97	8.5	43.76	8.26	97.58	23.39	139.8	21.16	91.58	18.02
CH14	88.9	21.48	77.9	9.02	44.1	9.11	100.65	24.11	141.03	22.66	90.67	17.95
CH15	88.05	21.89	76.44	8.37	41.95	8.65	97.98	23.9	138.07	23.85	91.47	18.57
CH16	87.74	20.92	75.65	9.3	42.44	8.34	101.81	24.39	141.86	23.19	92.65	18.03
CH17	92.47	22.15	78.58	9.21	45.21	8.49	103.43	24.25	147.39	21.93	96.67	19.82
CH18	93.42	22.83	79.22	9.74	47	7.99	101.82	24.52	148.97	23.93	98.71	19.79
CH19	90.36	20.77	78.25	8.96	44.69	7.89	104.48	23.88	147.62	23.16	94.8	19.2
CH20	85.83	21.21	74.86	9.7	43.15	9.89	98.13	23.25	140.31	21.92	91.84	19.03
CH21	89.85	20.84	76.05	8.8	44.54	7.32	99.03	22.97	137.5	22.73	90.02	17.58
CH22	90.04	21.36	79.61	9.7	44.15	8.16	98.04	22.96	142.65	21.47	95.62	18.51
CH23	88.74	22.11	77.34	9.04	42.83	8.18	100.12	24.14	143.22	22.65	94.85	19.34
CH24	91.96	22.4	80.11	9.84	44.89	8.63	104.39	24.78	143.85	21.32	96.99	19.9
CH25	89.27	20.76	75.85	9.18	44.47	7.47	98.89	23.89	146.75	22.89	97.83	20.09
CH27	87.67	20.2	76.95	8.63	42.9	8.81	100.27	22.29	140.4	21.11	92.43	17.8
CH28	89.52	21.69	77.24	9.04	45.46	8.94	101.47	23.93	146.85	22.19	96.74	19.69
CH29	88.57	21.26	76.01	9.47	45.07	8.63	103.97	24.1	150.71	21.75	99.18	20.09
DU01	105.45	18.07	85.91	9.12	66.69	5.63	71.08	18.63	121.51	14.19		
DU02	102.56	16.9	84.04	8.91	65.66	6.13	70.68	19.38	117.27	13.86		

DU05	131.77	28.41	101.2	10.62	83.77	11.25	87.91	24.94	146.78	18.28
DU06	117.47	19.49	92.22	10.75	73.53	6.71	79.92	20.36	136.04	16.57
DU07	104.48	17.92	83.35	8.78	66.65	5.67	72.99	18.52	124.03	14.46
DU08	126.7	22.03	101.66	11.44	81.92	7.74	81.38	21.17	137.02	17.04
DU09	98.63	18.55	83.51	8.5	64.76	5.39	67.12	16.33	112.71	12.14
DU11	125.85	21.69	92.99	9.54	79.9	9.45	81.32	22.64	142.48	16.92
DU12	110.93	19.43	91.87	9.62	73.51	8.09	77	19.81	131.7	14.38
DU13	134	27.95	103.58	11.48	85.22	7.93	87.31	25.98	143.36	18.22
DU14	94.04	15.35	72.65	8.87	58.51	5.95	72.32	18.94	121.77	14.61
DU15	105.5	16.9	83.87	7.2	65.68	6.05	75.41	18.74	128.12	15.46
DU17	111.93	20.4	92.92	9.53	75.49	7.07	73.17	19.17	125.87	14.61
DU19	110.04	19.03	89.02	9.42	71.29	7.16	77.76	18.96	131.92	14.91
DU20	104.96	17.67	89.41	9.1	70.79	6.31	72.07	17.6	121.16	13.24
DU22	102.38	16.92	86.53	8.37	69.34	6.24	70.81	18.15	120.16	12.9
DU23	106.76	19.31	90.99	9.82	70.48	7.1	76.55	19.85	125.05	14.6
DU24	139.75	28.08	107.67	11.32	85.54	8.59	91.53	26.44	139.89	18
DU25	119.08	25.05	89.05	10.34	74.48	8.21	78.09	21.08	130.77	12.94
DU26	101.65	16.86	82.7	9.16	64.44	5.82	66.9	18.02	119.07	13.78
DU27	126.56	21.64	93.93	10.71	81.21	8.74	82.42	21.33	139.89	17.26
DU28	97.76	15.25	81.35	8.65	67.24	7.48	73.2	18.5	123.09	14.15
DU30	107.92	15.96	85.24	8.28	70.51	6.97	79.76	19.13	132.31	15.31
DU31	103.94	17.28	83.24	8.39	65.58	5.99	73.25	18.88	124.54	14.27
DU32	114.36	18.27	92.22	10.23	75.78	8.53	81.8	21.3	144.68	18.01
DU33	100.99	17.23	82.73	7.81	63.85	5.41	68.22	18.07	116.85	13.06
DU34	98.99	16.99	81.65	8.61	64.75	5.5	66.95	18.13	117.13	12.84
DU35	104.17	15.99	81.93	7.99	66.43	6.74	73.98	20.08	126.96	15.91
DU36	105.3	17.49	85.25	8.59	67.54	5.92	73.24	17.69	122.87	12.78
DU37	113.86	18.09	90.06	8.99	76.76	8.81	76.52	20.41	131.57	15.96
DU38	104.17	15.57	82.83	8.11	68.71	5.95	80.84	20.23	129.06	15.93
DU39	126.85	23.43	99.02	8.64	74.97	7.08	78.94	19.91	136.76	15.01
DU40	105.93	17	87.13	8.76	68.84	7.74	74.54	19.46	122.62	14.19
DU43	108.41	17.14	88.41	9.01	71.78	6.31	75.81	17.89	125.38	14.69
DU44	126.86	22.02	97.44	8.6	76.37	6.84	81.17	21.74	134.2	15.85
DU45	111.5	17.55	91.18	10	73.76	5.31	78.55	19.61	132.09	15.16
DU46	110.08	19.45	92.78	9.37	70.09	7.07	74.47	19.37	127.24	14.11
DU47	121.54	23.27	98.05	9.59	76.49	7.08	77.73	21.06	131.61	18.44
DU48	130.21	24.11	96.51	10.23	76.99	8.09	82.65	21.68	136.82	17.09
DU49	96.55	15.39	79.55	7.61	60.79	5.81	67.66	16.6	118.3	12.74
DU50	105.67	17.71	87.58	7.89	69.55	6.95	76.15	18.94	131.89	14.66
DU52	105.13	17.99	85.14	8.76	70.2	5.82	71.17	19.02	126.03	14.61
DU53	100.7	16.23	85.29	8.69	70.06	6.84	69.41	17.13	116.64	13.16
DU56	109.37	20.54	90.63	9.07	72.17	7.24	72.02	20.87	125.48	14.3
DU90	105.31	16.95	85.02	9.62	69.52	6.29	72.77	18.3	124.6	15.04

DU92	103.39	16.45	81.96	8.04	65.19	5.32	70.11	18.15	122.63	13.95		
DU93	111.15	17.34	89.12	9.79	71.69	7.11	78.28	19.67	136.84	16.78		
DU94	113.07	17.34	90.34	8.71	72.98	6.1	76.53	17.9	132.95	15.81		
DU95	122.58	21.04	93.09	9.29	79.35	7.19	80.46	21.71	139.1	15.93		
DU96	122.27	23.64	94.8	10.73	73.89	6.05	75.45	18.84	130.51	19.9		
CB01	21.77	5.21	23.2	2.19	13.7	2.79	20.1	3.71	34.47	3.17	23.77	2.71
CB02	22.6	5.72	23.66	2.2	13.41	2.74	20.78	3.83	32.61	2.84	22.76	2.65
CB03	25.79	6.31	27.43	2.68	15.79	2.73	24.42	4.39	40.69	3.39	29.51	3.04
CB04	27.49	5.93	28.65	2.66	16.78	3.24	24.94	4.61	40.16	3.34	28.11	3.12
CB05	23.82	5.16	26.14	2.33	15.2	2.58	21.85	3.55	37.28	3.08	27	2.88
CB07	22.7	5.39	24.04	2.02	13.99	2.69	21.15	3.7	35.95	3.13	25.45	2.47
CB08	21.06	5.07	22.62	2.3	13.08	2.54	20.33	3.63	34.41	2.93	23.18	2.57
CB09	23.08	5.44	24.93	2.34	15.18	2.68	21.79	3.9	37.19	3.11	26.56	2.69
CB100	23.32	5.44	25.15	2.11	14.29	2.32	21.42	3.85	36.57	3.11	25.71	2.89
CB101	25	6.2	26.97	2.24	16.27	3.2	23.86	4.48	38.38	3.34	26.53	2.97
CB102	22.09	5.22	23.24	2.02	13.76	2.43	20.64	3.74	33.46	2.81	23.27	2.39
CB103	22.31	5.03	24.38	2.12	13.9	2.69	21.32	3.76	34.79	3.01	24.8	2.68
CB104	24.15	5	24.83	2.47	14.26	2.59	21.22	3.89	34.94	2.97	24.66	2.81
CB105	25.94	5.33	26.56	2.35	15.8	3.02	23.33	3.99	37.45	3.08	26.88	2.77
CB11	23.26	4.74	23.8	2	15.11	2.42	21.3	3.83	35.03	3.12	24.83	2.47
CB12	23.17	5.99	23.87	2.03	14.42	2.57	21.6	4.06	35.5	2.92	24.59	2.53
CB14	23.59	5.6	25.16	2.27	14.37	2.55	21.56	3.83	37.16	2.82	26.74	2.8
CB16	22.64	5.36	24.1	2.1	14.16	2.72	20.95	3.86	35.69	2.82	25.43	2.7
CB17	22.82	5.4	24.26	2.09	13.7	2.73	21.32	3.84	34.4	3.1	24.11	2.66
CB18	22.49	5.31	23.8	2.24	13.78	2.58	20.55	3.58	34.51	2.95	23.14	2.64
CB20	23.03	5.58	24.24	2.24	13.93	2.87	21.37	3.82	34.32	2.71	23.83	2.71
CB21	24.19	5.61	25.9	1.95	14.79	2.51	22.15	3.83	37.36	3.21	26.33	2.87
CB22	21.64	4.93	23.8	2.24	13.48	2.46	20.47	3.45	34.74	2.81	23.63	2.41
CB23	23.73	5.4	25.48	2.17	15.2	2.65	22.3	3.86	37.33	3.11	26.51	2.53
CB24	22.1	4.92	23.83	2.08	13.94	2.87	20.54	3.7	34.51	3.06	23.93	2.65
CB25	22.35	5.31	23.48	2.46	13.99	2.51	21	3.76	35.04	2.8	24.92	2.67
CB26	24.75	4.93	26.42	2.12	15.19	2.39	23.14	3.62	37.52	2.77	26.1	2.65
CB28	23.81	5.33	24.81	2.17	14.28	2.8	21.46	3.92	36.53	3.01	25.13	2.63
CB29	24.66	5.6	25.47	2.54	15.23	2.86	23.28	4.19	38.47	3.25	28.26	2.82
CB31	24.5	5.09	27.78	2.31	16.35	3.18	24.47	4.17	41.12	3.41	29.35	2.9
CB32	25.18	6.2	26.69	2.68	15.91	3.42	23.13	4.04	37.96	3.2	26.6	2.9
CB33	25.66	6.15	27.49	2.47	16.1	2.86	23.71	4.36	38.94	3.37	27.53	2.93
CB34	25.5	6.14	27.49	2.17	16.13	3.2	23.86	4	39.94	3.61	28.05	2.87
CB35	22.74	5.01	24.35	1.92	13.62	2.75	20.65	3.66	34.68	2.91	24.29	2.77
CB36	25.02	5.88	26.62	2.42	15.59	3.13	23.34	4.09	37.8	3.17	25.96	2.72
CB37	26.62	6.46	29.24	2.55	17.34	3.39	25.11	4.26	41.79	3.89	28.5	2.84
CB38	24.62	5.78	26.69	2.33	15.47	2.89	23.92	3.98	39.43	3.05	27.91	2.78
CB39	25.7	6.12	27.9	2.59	16.25	2.9	24.15	4.17	39.03	3.34	27.55	2.83

CB40	26.59	6.14	29.21	2.35	17.15	3.35	25.11	4.25	41.68	4.07	28.94	2.64
CB41	26.3	6.19	27.49	2.28	16.59	3.01	24.19	4.32	40.6	3.41	28.12	3.17
CB42	25.26	5.94	27.65	2.23	15.93	3.29	23.75	4.27	40.57	3.73	27.8	2.99
CB43	25.4	6.02	27.4	2.7	16.39	2.54	23.41	4.37	38.05	3.48	25.63	2.83
CB46	25.77	5.86	28.5	1.74	16.42	2.94	24.17	4.22	39.89	3.88	27.71	3.06
CB47	27.13	6.4	29.11	1.76	17.14	3.57	25.79	4.7	42.22	3.98	30.06	3.34
CB48	24.75	5.77	26.87	2.46	15.63	3.07	23.7	4.09	39.04	3.33	27.43	2.98
CB49	23.76	5.7	25.06	2.53	14.49	3.03	21.94	4.19	35.38	3.37	24.29	2.95
CB51	22.89	5.44	25.93	2.43	15.39	2.48	21.84	3.78	37.64	3.07	26.26	2.86
CB53	24.83	5.98	25.49	1.75	15.53	3.02	22.82	3.86	37.86	2.93	26.75	2.91
CB55	25.62	6.09	27.67	2.59	16.52	3.1	23.91	4.19	40.29	3.47	28.14	2.99
CB56	25.86	5.83	26.9	2.35	15.97	3.33	22.99	4.22	39.12	4.22	27.39	2.93
CB56a	25.46	6.03	26.74	2.42	15.79	3.08	23.2	4.19	37.59	3.24	26.29	2.75
CB57	25.33	6.39	26.84	2.2	15.17	3.25	23.99	4.47	38.95	3.45	27.18	3.06
CB58	24.93	6.06	26.01	2.41	15.52	2.92	22.35	3.95	37.03	2.94	25.75	2.87
CB59	25.58	6.14	26.64	2.23	15.39	3.09	23.36	4.03	38.18	3.06	26.5	3.03
CB60	23.77	5.4	25.89	2.21	15.07	3.02	22.43	4.1	37.36	3.1	25.92	2.86
CB61	23.68	5.81	25.67	2.25	14.73	2.71	21.96	3.79	36.14	2.84	24.96	2.81
CB62	24.85	6.26	26.89	2.19	15.97	3.66	23.08	4.27	38.69	3.37	27.03	3.21
CB63	25.4	5.4	26.13	2.13	15.33	2.9	23.11	3.73	39.88	4.54	27.37	3.02
CB63b	24.87	5.91	25.84	2.26	15.1	3.13	23	4.03	37.69	3.13	26.03	2.87
CB64	26.71	6.01	28.35	2.53	16.32	2.99	25.12	4.11	41.23	3.34	28.99	2.93
CB65	24.83	6.4	25.84	2.61	15.18	3	22.3	3.94	36.13	3.24	25.27	2.83
CB66	25.83	5.86	27.78	2.44	15.94	3.32	24.06	4.04	40.23	3.36	27.33	3.04
CB90	24.09	6.15	26.03	2.55	15.25	2.96	22.88	4.12	37.36	3.15	26.77	2.7
CB91	22.85	5.54	23.5	2.24	13.82	2.95	21.53	3.89	34.99	2.82	23.49	2.58
CB97	23.91	5.7	24.7	1.68	14.16	2.87	22.02	3.71	36.29	3.06	25.39	2.5
CB99	26.6	6.63	28.17	2.82	16.41	3.29	25.2	4.4	40.04	3.51	28.6	3.03

b. Embryonic

	hum_l	hum_w	rad_l	rad_w	carp_l	carp_w	fem_l	fem_w	tib_l	tib_w	tar_l	tar_w
CH01	1.89	0.21	1.65	0.32	1.59	0.57	2.19	0.4	2.81	0.43	1.08	0.9
CH03	3.15	0.41	2.19	0.31	1.99	0.94	2.09	0.33	3.16	0.26	1.44	1.26
CH04	2.13	0.46	2.21	0.36	1.67	0.51	1.04	0.48	1.87	0.28	1.26	1.08
CH06	2.78	0.54	2.57	0.32	1.82	0.76	2.17	0.32	2.94	0.26	1.24	1.32
CH08	2.69	0.58	2.2	0.47	1.52	0.33	3.46	0.49	3.58	0.76	2.36	1
CH09	2.78	0.49	2.34	0.34	1.51	0.33	3.73	0.57	3.9	0.86	2.59	0.88
CH10	2.66	0.61	2.24	0.36	1.43	0.36	3.63	0.56	3.91	0.63	2.29	0.94
CH11	2.45	0.47	2.16	0.36	1.38	0.32	3.38	0.58	3.78	0.52	2.39	0.82
CH12	2.68	0.93	2.43	0.35	1.5	0.44	3.79	0.53	3.82	0.52	2.47	0.89
CH13	2.65	0.44	2.3	0.37	1.38	0.36	3.61	0.56	3.86	0.58	2.5	0.86
CH14	2.9	0.47	2.44	0.47	1.62	0.36	3.63	0.52	4	0.8	2.25	1.04

CH15	2.81	0.39	2.39	0.41	1.53	0.36	3.57	0.62	3.9	0.52	2.35	0.94
CH16	2.67	0.71	2.3	0.4	1.45	0.42	3.2	0.58	3.59	0.85	2.11	0.81
CH17	2.65	0.44	2.07	0.36	1.32	0.27	3.28	0.53	3.66	0.58	2.35	0.95
CH18	2.75	0.54	2.26	0.42	1.46	0.39	2.84	0.56	3.68	0.79	2.45	0.81
CH19	2.53	0.6	2.21	0.45	1.53	0.47	3.77	0.53	3.93	0.86	2.44	0.87
CH20	2.29	0.65	1.94	0.34	1.22	0.42	2.98	0.54	3.13	0.89	1.92	0.91
CH21	2.46	0.4	1.98	0.32	1.17	0.38	3.01	0.49	2.99	0.66	1.93	1.07
CH22	2.67	0.44	2.15	0.38	1.48	0.43	3.28	0.49	3.49	0.91	2.45	0.87
CH23	1.96	0.34	1.61	0.33	1.12	0.48	2.55	0.55	2.47	0.7	1.51	0.78
CH24	2.61	0.48	2.18	0.41	1.44	0.3	3.61	0.68	4.11	0.85	2.51	0.96
CH25	2.41	0.5	2.28	0.34	1.51	0.32	3.44	0.62	3.54	0.81	2.33	1.01
CH26	2.93	0.49	2.35	0.43	1.49	0.34	3.82	0.58	3.53	0.98	2.72	1.12
CH27	2.31	0.5	2.32	0.25	1.44	0.48	3.41	0.54	4.06	0.96	2.57	1.19
CH28	2.69	0.49	2.02	0.31	1.34	0.41	3.58	0.57	3.89	1.01	2.63	1.09
CH29	2.93	0.51	2.28	0.28	1.52	0.46	3.12	0.63	4.28	0.96	2.78	1.07
CH30	2.61	0.45	2.17	0.4	1.34	0.56	3.65	0.53	3.44	0.77	2.2	1.14
DU01	2.91	0.37	2.86	0.4	1.38	0.35	0.96	0.25	5.06	0.4	2.67	0.91
DU02	3.28	0.42	3.6	0.41	1.67	0.44	3.34	0.5	5.69	0.97	3.08	1.04
DU03	3.18	0.4	3.13	0.47	1.58	0.6	3.32	0.64	5.81	0.65	3.21	1.19
DU04	2.7	0.41	2.62	0.29	1.42	0.6	3.09	0.48	4.63	0.34	2.4	1.13
DU05	3	0.61	2.72	0.35	1.37	0.5	3.29	0.65	4.95	0.55	2.51	1.05
DU06	3.53	0.37	3.74	0.44	1.98	0.47	3.73	0.59	6.05	0.82	3.65	1.09
DU07	2.89	0.33	2.63	0.31	0.86	0.35	3.43	0.53	5.04	0.39	2.58	0.9
DU08	3.48	0.36	3.15	0.38	1.55	0.37	2.87	0.31	3.86	0.38	2.1	0.9
DU09	2.94	0.62	2.4	0.25	1.1	0.37	3.17	0.4	4.57	0.71	2.59	0.94
DU10	2.5	0.41	2.3	0.23	1.15	0.43	2.59	0.52	4.27	0.52	2.12	0.69
DU11	3.18	0.43	3.03	0.37	1.6	0.43	3.33	1.85	5.16	0.37	2.56	0.99
DU12	3.11	0.42	2.82	0.32	1.45	0.39	3.36	0.5	5.11	0.89	2.33	0.69
DU13	3.36	0.4	3.31	0.3	1.66	0.38	3.65	0.49	5.62	0.72	2.91	0.99
DU14	3.61	0.46	2.71	0.3	1.84	0.32	3.64	0.47	5.33	0.5	2.13	0.81
DU15	3.16	0.5	2.6	0.25	1.23	0.47	2.66	0.51	3.95	0.47	2.29	0.81
DU16	3.19	0.49	2.95	0.37	1.78	0.47	3.77	0.47	4.9	0.59	2.67	0.88
DU17	2.94	0.35	2.71	0.34	1.38	0.33	3.21	0.51	4.31	0.93	2.21	0.9
DU18	1.87	0.36	2.12	0.3	0.95	0.36	1.83	0.36	3.19	0.6	1.51	0.73
DU19	3.77	0.44	3.48	0.27	1.65	0.33	3.59	0.59	5.6	0.67	2.88	1.06
DU20	3.83	0.47	3.16	0.41	1.7	0.39	3.72	0.61	5.65	0.86	2.81	0.95
DU21	2.55	0.32	2.57	0.27	1.21	0.37	3.08	0.48	4.33	0.59	2.34	0.73
DU22	2.42	0.3	2.25	0.26	1.18	0.29	2.78	0.38	3.88	0.47	2.19	0.7
DU23	3.03	0.32	2.89	0.3	1.42	0.45	3.38	0.46	4.81	0.57	2.55	0.92
DU24	3.54	0.43	3.25	0.3	1.41	0.39	3.36	0.52	4.94	0.62	2.68	0.92
DU25	3.52	0.46	3.1	0.32	1.45	0.47	3.52	0.48	5.19	0.72	2.57	0.93
DU26	2.35	0.33	2.26	0.22	1.12	0.46	2.12	0.41	3.8	0.5	2.08	1.03
DU27	3.05	0.28	2.93	0.28	1.36	0.36	2.69	1.43	4.14	0.83	2.35	0.95

DU28	3.07	0.36	2.66	0.26	1.31	0.35	3.06	0.56	5.16	0.61	2.48	0.71
DU29	2.05	0.36	2.35	0.29	1.12	0.48	2.75	0.51	3.97	0.56	1.94	0.47
CB01	3.27	0.58	3.23	0.45	1.8	0.22	3.17	0.32	4.54	0.71	3.2	0.59
CB02	2.95	0.47	3.05	0.3	1.77	0.31	3.18	0.51	4.27	0.54	3.27	0.57
CB03	3.07	0.53	3.15	0.36	1.56	0.28	3	0.48	3.93	0.76	2.93	0.51
CB05	3.21	0.63	3.44	0.35	2.02	0.39	2.9	0.5	5.03	0.69	3.77	0.63
CB06	3.31	0.56	3.38	0.33	1.88	0.3	3.63	0.42	4.62	0.58	3.36	0.47
CB07	2.32	0.32	1.92	0.24	1.16	0.22	2.49	0.26	3.27	0.47	2.23	0.43
CB08	3.05	0.86	2.8	0.31	1.38	0.33	3.06	0.48	4.19	0.66	2.57	0.58
CB09	2.13	0.4	2.04	0.28	1.13	0.33	2.65	0.54	3.08	0.5	2	0.78
CB10	1.74	0.03	1.6	0.2	0.86	0.38	2	0.33	2.55	0.51	1.62	0.74
CB11	1.95	0.43	1.97	0.22	1.2	0.41	1.92	0.37	2.64	0.39	1.93	0.62
CB12	2.01	0.41	2.25	0.3	1.38	0.43	2.47	0.53	2.89	0.29	1.8	0.66
CB13	3.54	0.82	3.11	0.33	1.67	0.36	3.74	0.5	4.64	0.59	2.95	0.6
CB14	3.21	0.71	3.14	0.29	2.18	0.43	3.1	0.55	3.92	0.89	3.1	0.64