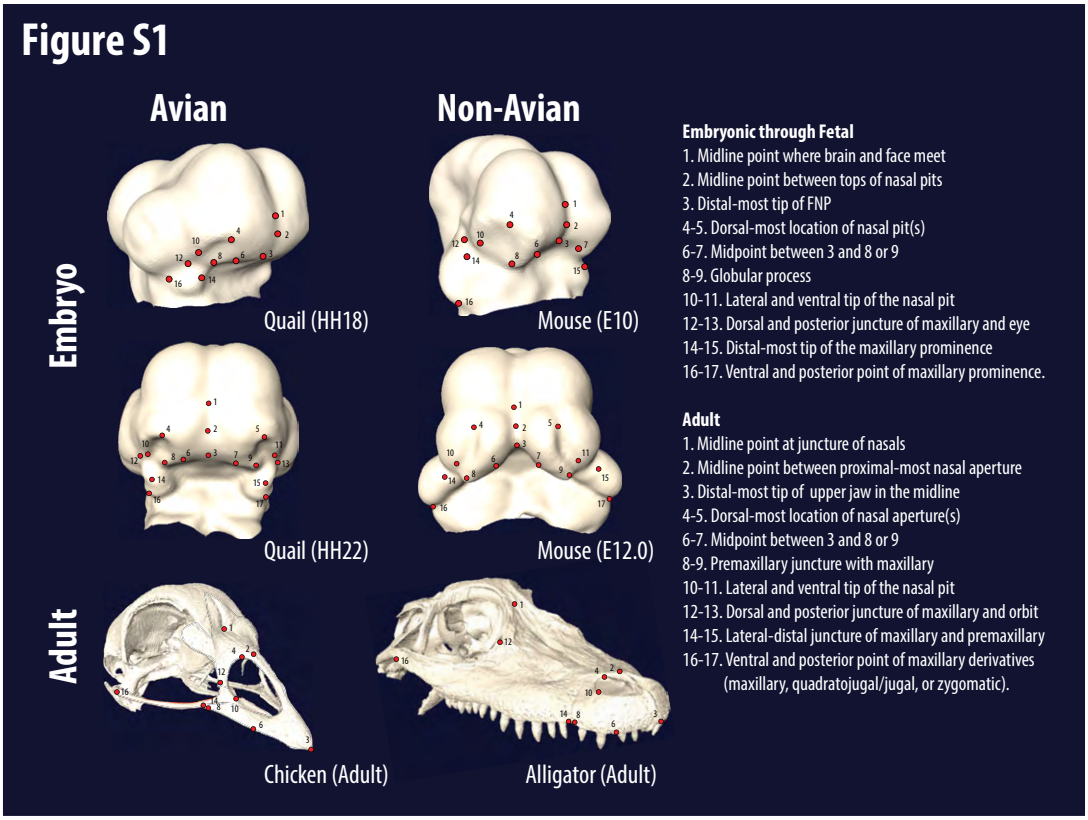

Figure S1: Morphometric Landmarks. Representative embryos and adults are shown with the location of landmarks and their descriptions. Surface landmarks and skeletal landmarks are considered to be homologous locations for the purpose of morphometric analysis. To choose these landmarks we tracked surface features of the facial prominences from prominence outgrowth to fusion and later fetal growth. Skeletal derivatives in adults were matched to surface fetal structures using generalized descriptions and published fate mapping (e.g., assuming that the distal tip of the embryonic frontonasal process corresponds to the distal tip of the adult upper jaw).

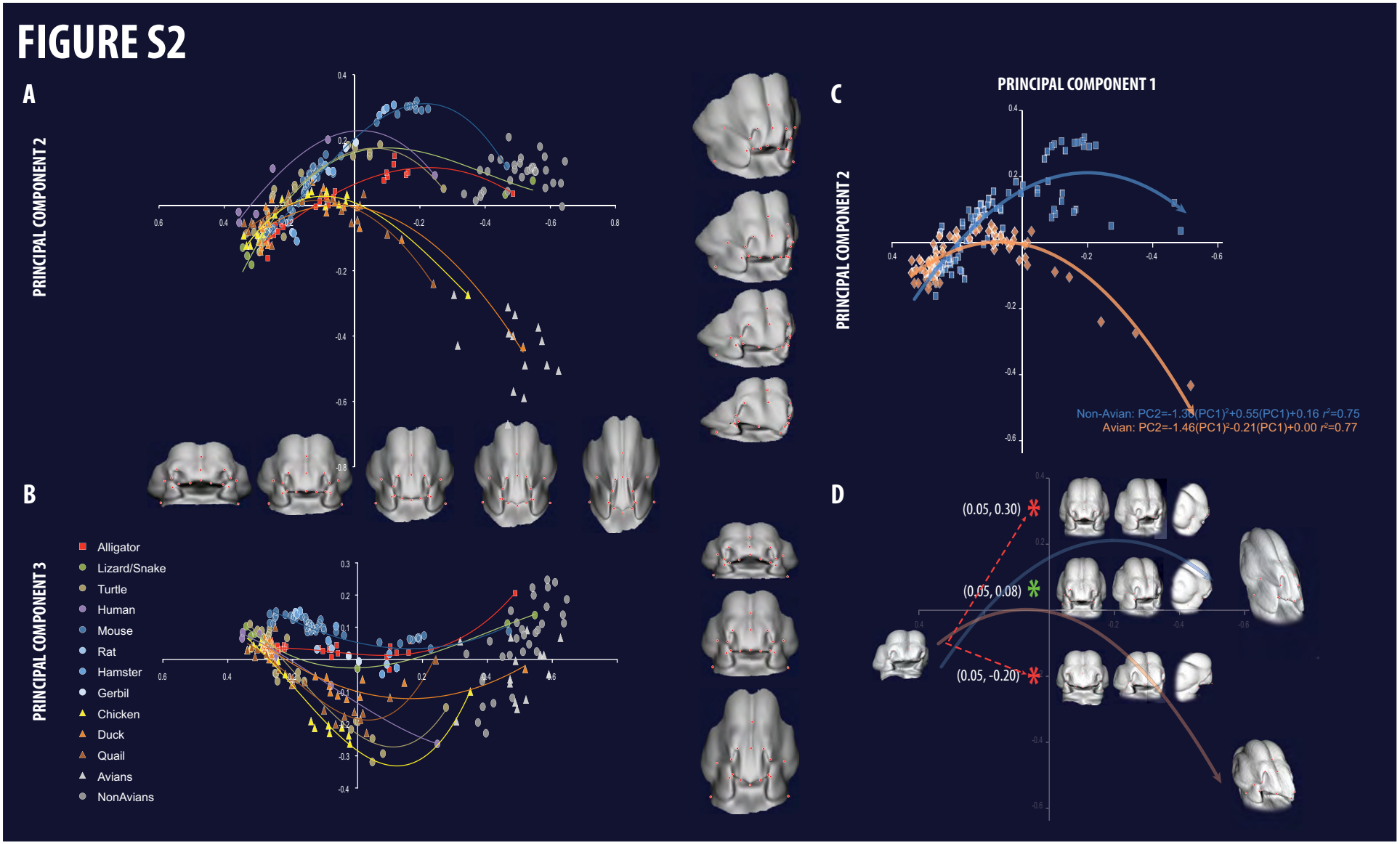

Figure S2. PCA axes in two-dimensional scatterplots. **A**. PC1 versus PC2. **B**. PC1 versus PC3. **C**. Estimated average non-avian (blue squares) and avian (red diamonds) PC1-2 developmental trajectories (lines). **D**. Estimated landmark configurations and embryo morphologies of trajectories above, within, and below amniote averages at common PC1 (developmental age/facial length).

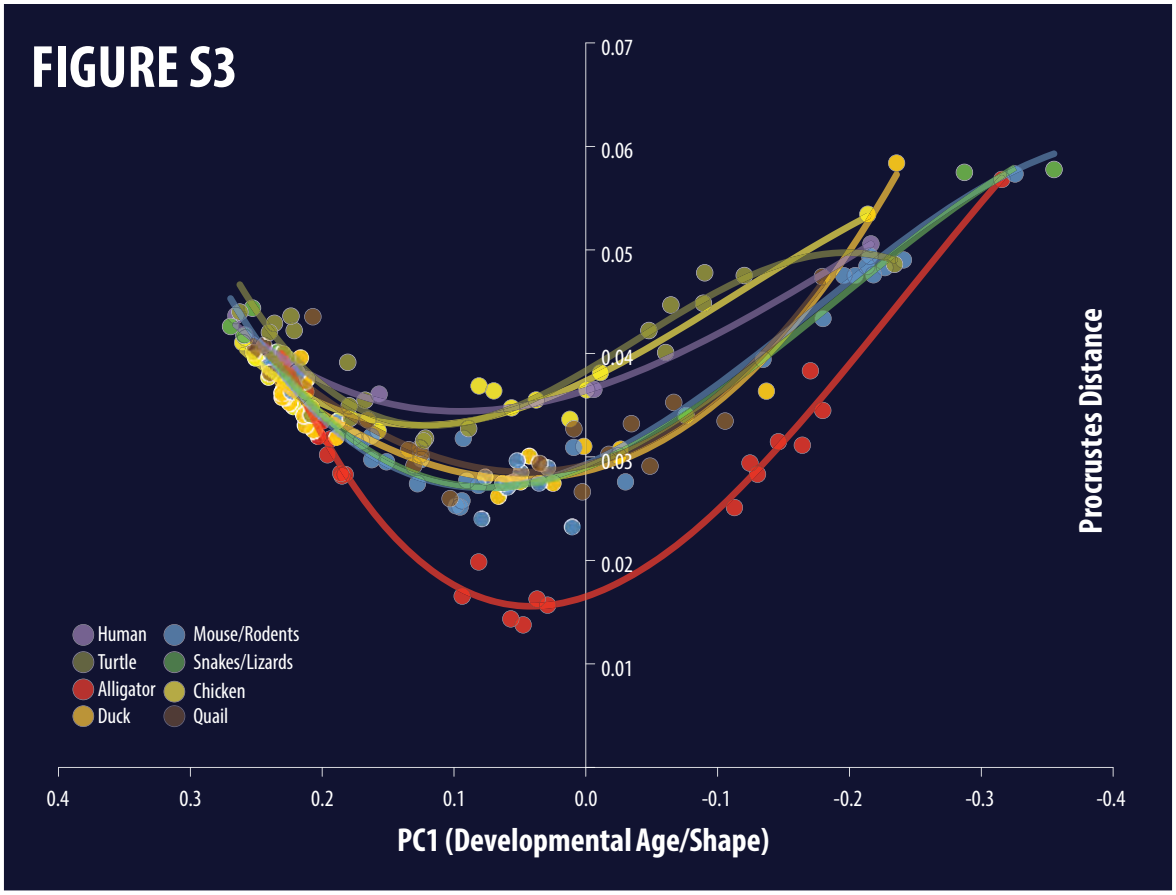

Figure S3. Average Procrustes distance for each species. Data from Figure 1B plotted for individual species. All species are most convergent with the average facial shape at or near the time of facial primordial fusion, after which shape diversity steadily increases.

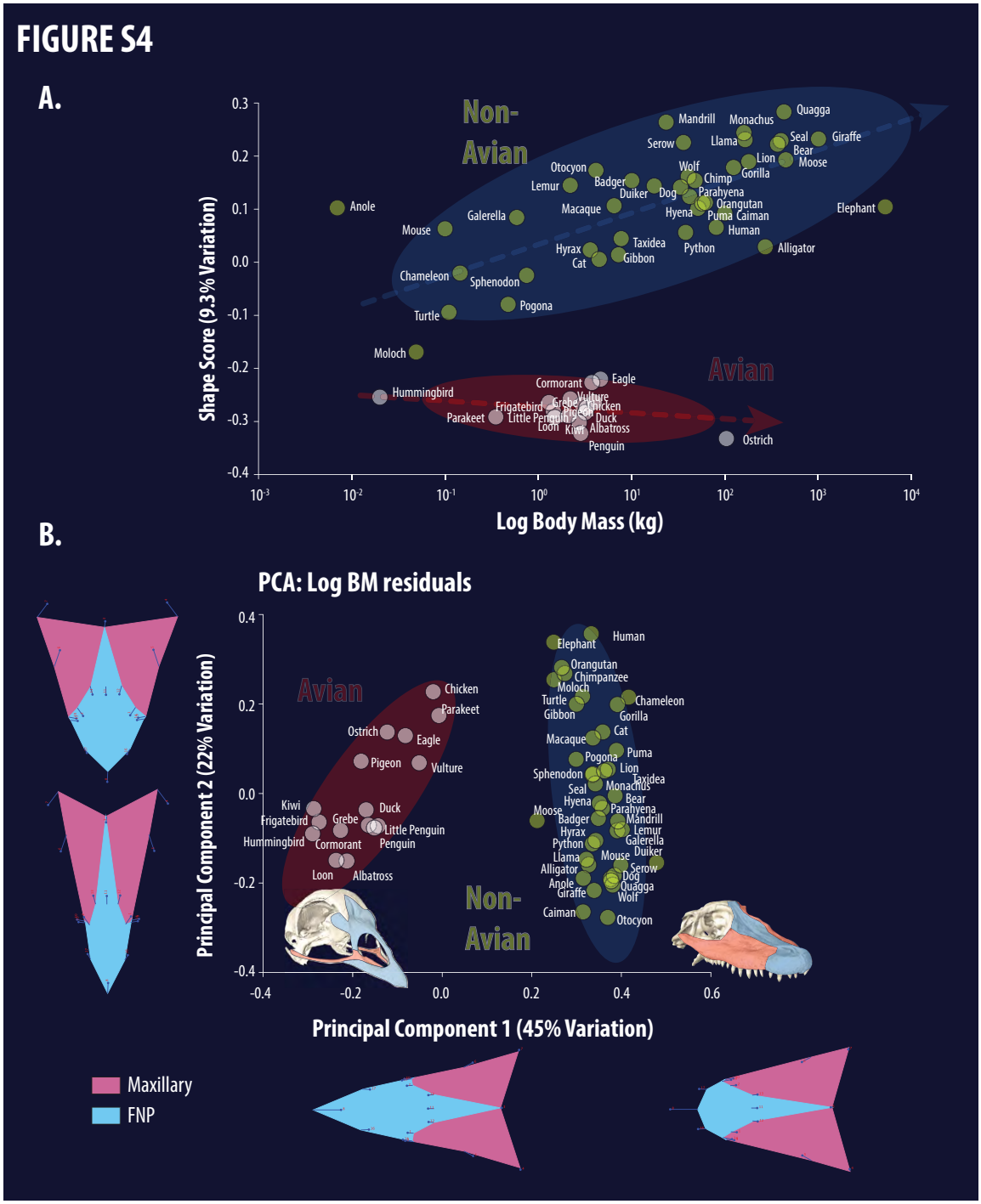

Figure S4. Allometry and shape comparison in adult amniote skulls. **A**. Multivariate regression of log body mass (kg) on shape reveals divergence in shape-size relationship between non-avian and avian amniote adults. **B**. PCA of body-mass/shape residuals from (**A**) demonstrates that the relative proportions of the maxillary and FNP-derivatives (PC1) separate avians and non-avians even when accounting for allometry, while in both groups longer skulls tend to be narrower (PC2). Mean landmark configurations are shown in dorsal view with vectors showing direction and magnitude of eigenvectors. Faces color-coded according to developmental derivatives (maxillary=red, FNP=blue).

Figure S5

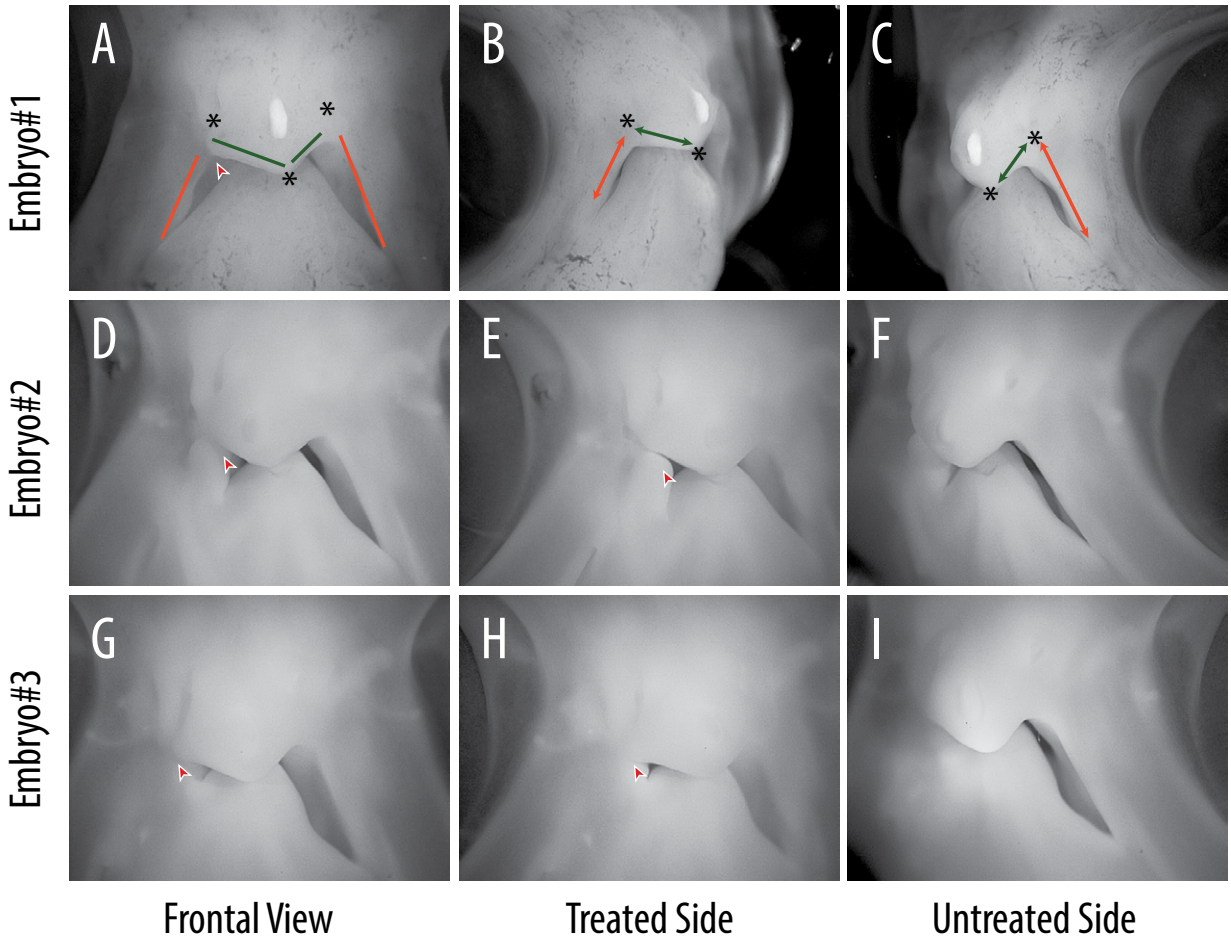

Figure S5. Additional experimental outcomes. We performed a dual experimental treatment in which both a SHH-N bead was placed in the FNP and Ptc-Δ-loop was electroporated into the maxillary at HH15-16. All embryos (N=3) exhibited reduced maxillaries and expanded FNPs (compare arrows on treated versus untreated sides), as well as clefts of the primary palate (red arrows) compared to untreated sides.

Table S1: Embryonic sample age composition (Hrs=hours incubation, CS=Carnegie stage, TS=tail somites, Th=Theiler stage).

Common	Order	Species	Unit	Age	N
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	216	1
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	240	2
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	264	2
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	288	3
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	312	3
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	360	3
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	384	3
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	456	3
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	480	2
Alligator	Crocodilia	*Alligator mississippiensis*	Hrs	528	2
Ball python	Reptilia	*Elaphe guttata*	Hrs	192	1
Chameleon	Reptilia	*Chameleo chameleon*	Hrs	168	6
Turtle	Testudines	*Trachemys scripta*	Hrs	168	5
Turtle	Testudines	*Trachemys scripta*	Hrs	192	3
Turtle	Testudines	*Trachemys scripta*	Hrs	264	4
Turtle	Testudines	*Trachemys scripta*	Hrs	288	3
Turtle	Testudines	*Trachemys scripta*	Hrs	360	3
Turtle	Testudines	*Trachemys scripta*	Hrs	384	3
Human	Mammalia	*Homo sapiens*	CS	14	1
Human	Mammalia	*Homo sapiens*	CS	15	1
Human	Mammalia	*Homo sapiens*	CS	16	1
Human	Mammalia	*Homo sapiens*	CS	17	1
Human	Mammalia	*Homo sapiens*	CS	18	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	1	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	2	3
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	3	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	7	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	8	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	10	2
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	11	2
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	12	1
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	13	2
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	15	2
Mouse	Mammalia	*Mus musculus* (C57bl)	TS	16	2
Mouse	Mammalia	*Mus musculus* (C57bl)	Th	11.5	15
Mouse	Mammalia	*Mus musculus* (C57bl)	Th	12.5	8
Rat	Mammalia	*Rattus norvegicus*	Th	12	1
Rat	Mammalia	*Rattus norvegicus*	Th	13	2
Rat	Mammalia	*Rattus norvegicus*	Th	14	1
Hamster	Mammalia	*Mesocricetus auratus*	Th	9	2
Hamster	Mammalia	*Mesocricetus auratus*	Th	10	2
Hamster	Mammalia	*Mesocricetus auratus*	Th	11	3
Gerbil	Mammalia	*Meriones unguiculatus*	Th	16	2

Chicken	Aves	*Gallus gallus*	Hrs	84	3
Chicken	Aves	*Gallus gallus*	Hrs	96	4
Chicken	Aves	*Gallus gallus*	Hrs	108	1
Chicken	Aves	*Gallus gallus*	Hrs	120	2
Chicken	Aves	*Gallus gallus*	Hrs	132	2
Chicken	Aves	*Gallus gallus*	Hrs	144	2
Chicken	Aves	*Gallus gallus*	Hrs	156	6
Duck	Aves	*Anas platyrhynchos*	Hrs	102	3
Duck	Aves	*Anas platyrhynchos*	Hrs	120	8
Duck	Aves	*Anas platyrhynchos*	Hrs	138	2
Duck	Aves	*Anas platyrhynchos*	Hrs	144	1
Duck	Aves	*Anas platyrhynchos*	Hrs	150	1
Duck	Aves	*Anas platyrhynchos*	Hrs	162	2
Duck	Aves	*Anas platyrhynchos*	Hrs	168	1
Duck	Aves	*Anas platyrhynchos*	Hrs	174	1
Duck	Aves	*Anas platyrhynchos*	Hrs	180	3
Duck	Aves	*Anas platyrhynchos*	Hrs	186	1
Duck	Aves	*Anas platyrhynchos*	Hrs	204	1
Quail	Aves	*Coturnix coturnix*	Hrs	72	1
Quail	Aves	*Coturnix coturnix*	Hrs	84	2
Quail	Aves	*Coturnix coturnix*	Hrs	96	4
Quail	Aves	*Coturnix coturnix*	Hrs	114	3
Quail	Aves	*Coturnix coturnix*	Hrs	120	3
Quail	Aves	*Coturnix coturnix*	Hrs	126	1
Quail	Aves	*Coturnix coturnix*	Hrs	144	5
Quail	Aves	*Coturnix coturnix*	Hrs	168	1
Quail	Aves	*Coturnix coturnix*	Hrs	216	1

Table S2: Adult Sample and Body Masses (NSF Digital Morphology Library at the University of Texas, Austin [NSF], www.digimorph.org, Ohio University Visible Interactive Alligator [VIA], www.oucom.ohiou.edu/dbms-witmer/3D_gator.htm, Kyoto University Primate Research Institute Digital Morphology Museum, [KU], www2.pri.kyoto-u.ac.jp/dmm/WebGallery/index.html).

Species (common name)	Group	3D Source	BM (kg)	log BM
Anas platyrhynchos (white pekin duck)	Avian	NSF	3.2	0.51
Apteryx australis (kiwi)	Avian	NSF	3.3	0.52
Brotogeris chrysopterus (parakeet)	Avian	NSF	0.35	-0.46
Columba livia (pigeon)	Avian	Paper	2.1	0.32
Coragyps atratus (black vulture)	Avian	NSF	2.2	0.34
Diomedea immutabilis (albatross)	Avian	NSF	2.75	0.44
Eudyptula minor (little penguin)	Avian	NSF	1.5	0.18
Fregata magnificens (frigatebird)	Avian	NSF	1.45	0.16
Gallus gallus (chicken)	Avian	NSF	2.94	0.47
Gavia immer (common loon)	Avian	NSF	4	0.60
Haliaeetus leucocephalus (bald eagle)	Avian	NSF	4.65	0.67
Patagona gigas (hummingbird)	Avian	NSF	0.02	-1.70
Phalacrocorax sp. (cormorant)	Avian	NSF	3.75	0.57
Podilymbus podiceps (grebe)	Avian	NSF	1.3	0.11
Spheniscus demersus (penguin)	Avian	NSF	2.85	0.45
Struthio camelus (ostrich)	Avian	NSF	104	2.02
Alces alces (moose)	Non-avian	NSF	450	2.65
Alligator mississippiensis (alligator)	Non-avian	VIA	271.5	2.43
Anolis carolinensis (green anole)	Non-avian	NSF	0.007	-2.15
Caiman sp. (caiman)	Non-avian	KU	100	2.00
Canis familiaris (dog)	Non-avian	KU	33.5	1.53
Canis lupus (wolf)	Non-avian	KU	40.5	1.61
Capricornis crispus (serow)	Non-avian	NSF	36	1.56
Cephalophus sp. (duiker)	Non-avian	NSF	17.5	1.24
Chameleo chameleon (chameleon)	Non-avian	NSF	0.145	-0.84
Elephas maximus (Asian elephant)	Non-avian	NSF	5250	3.72
Equus quagga (quagga)	Non-avian	KU	430.5	2.63
Felis concolor (puma)	Non-avian	KU	62	1.79
Felis leo (lion)	Non-avian	NSF	180.5	2.26
Galerella sanguinea (slender mongoose)	Non-avian	NSF	0.5875	-0.23
Giraffa camelopardalis (giraffe)	Non-avian	NSF	1010	3.00
Glyptemys muhlenbergii (turtle)	Non-avian	NSF	0.11	-0.96
Gorilla gorilla (gorilla)	Non-avian	KU	124	2.09

Homo sapiens (human)	Non-avian	KU	81	1.91
Hyaena hyaena (hyaena)	Non-avian	NSF	51.5	1.71
Hydrurga leptonyx (leopard seal)	Non-avian	NSF	400	2.60
Hylobates lar (gibbon)	Non-avian	KU	7.25	0.86
Lama glama (llama)	Non-avian	NSF	165	2.22
Lemur catta (lemur)	Non-avian	KU	2.2	0.34
Macaca mulatta (macaque)	Non-avian	KU	6.5	0.81
Mandrillus sphinx (mandrill)	Non-avian	KU	23.5	1.37
Mayailurus iriomotenis (iriomote cat)	Non-avian	KU	4.5	0.65
Meles meles (badger)	Non-avian	KU	10.05	1.00
Moloch horridus (thorny devil)	Non-avian	NSF	0.049	-1.31
Monachus tropicalis (monk seal)	Non-avian	NSF	160	2.20
Mus musculus (mouse)	Non-avian	NSF	0.1	-1.00
Otocyon megalotis (bat-eared fox)	Non-avian	NSF	4.15	0.62
Pan troglodytes (chimpanzee)	Non-avian	KU	48	1.68
Parahyaena brunnea (brown hyena)	Non-avian	NSF	42	1.62
Pogona vitticeps (bearded dragon)	Non-avian	NSF	0.475	-0.32
Pongo pygmaeus (orangutan)	Non-avian	KU	57.5	1.76
Procavia capensis (hyrax)	Non-avian	NSF	3.6	0.56
Python molurus (python)	Non-avian	NSF	38	1.58
Sphenodon punctatus (tuatara)	Non-avian	NSF	0.75	-0.12
Taxidea taxus (badger)	Non-avian	NSF	7.75	0.89
Ursus horribilis (grizzly bear)	Non-avian	NSF	367.5	2.57

Table S3: Distance matrices between species means (Procrustes above diagonal, Mahalanobis (D^2) below)

D2/Pr	Al	Ch	Du	Ge	Ha	Hu	Sq	Mo	Qu	Ra	Tu
Alligator	0.00	0.17	0.14	0.23	0.20	0.14	0.18	0.16	0.20	0.20	0.00
Chicken	15.97	0.00	0.10	0.27	0.22	0.13	0.19	0.12	0.24	0.19	15.97
Duck	14.21	8.79	0.00	0.22	0.21	0.12	0.16	0.07	0.18	0.17	14.21
Gerbil	17.23	22.00	17.62	0.00	0.19	0.25	0.14	0.25	0.14	0.26	17.23
Hamster	13.31	16.70	15.69	16.21	0.00	0.23	0.19	0.21	0.22	0.28	13.31
Human	13.66	10.29	9.89	20.93	16.22	0.00	0.19	0.14	0.20	0.15	13.66
Squamate	16.56	20.68	16.51	9.01	16.29	21.24	0.00	0.20	0.13	0.22	16.56
Mouse	14.59	9.45	6.80	21.19	17.20	9.77	20.66	0.00	0.21	0.16	14.59
Quail	15.16	20.95	16.38	8.98	15.49	19.36	10.63	18.98	0.00	0.24	15.16
Rat	16.58	15.49	12.64	21.12	20.60	13.62	19.64	11.98	20.25	0.00	16.58
Turtle	0.00	0.17	0.14	0.23	0.20	0.14	0.18	0.16	0.20	0.20	0.00

Table S4: Significance levels of distances between species means (Procrustes distances above diagonal, Mahalanobis distances (D^2) calculated from the Canonival Variates Analysis below)

D2/Pr	Al	Ch	Du	Ge	Ha	Hu	Sq	Mo	Qu	Ra	Tu
Alligator	-	0.001	0.000	0.008	0.006	0.002	0.000	0.001	0.162	0.001	-
Chicken	0.001	-	<.0001	0.003	0.001	0.001	0.001	0.000	0.128	0.000	0.001
Duck	0.000	<.0001	-	0.000	0.000	<.0001	<.0001	0.059	0.021	<.0001	0.000
Gerbil	0.009	0.001	0.000	-	0.065	0.001	0.042	0.002	1.000	0.002	0.009
Hamster	0.007	0.001	0.000	0.008	-	0.002	0.002	0.001	0.326	0.001	0.007
Human	0.002	0.001	<.0001	0.003	0.003	-	<.0001	0.002	0.045	0.000	0.002
Squamate	0.001	0.000	<.0001	0.003	0.002	0.000	-	0.000	0.087	<.0001	0.001
Mouse	0.001	0.000	<.0001	0.003	0.001	0.001	0.000	-	0.243	0.243	0.001
Quail	0.143	0.094	0.053	0.200	0.125	0.095	0.128	0.119	-	0.081	0.143
Rat	<.0001	0.000	<.0001	0.000	0.001	<.0001	<.0001	0.000	0.049	-	<.0001
Turtle	-	0.001	0.000	0.008	0.006	0.002	0.000	0.001	0.162	0.001	-