**ESM – TITLES AND LEGENDS. DJ BIRD**

**Supplementary movie S1. Animated 3D model of an arctic fox (*Vulpes lagopus*) skull featuring the cribriform plate and general nasal anatomy.**

The cribriform plate (red) model clearly displays the perforations, or foramina, through which axon bundles from olfactory sensory neurons pass en route to the olfactory bulb of the brain. Sensory neurons in the olfactory epithelium are located primarily on the ethmoturbinal (green) and nasoturbinal (yellow) bones. Maxillary turbinals, which carry respiratory epithelium are shown in blue. The arctic fox is not among the sample species but its model is used here because of its particular clarity.

**Supplementary figure S2. Time-calibrated phylogeny of sample species**. Tree compiled from published molecular phylogenies [32,33] (See Main References).

**Supplementary table S3. Key resource table for sample specimens, CT scanning machines and facilities, digital imaging software, and resource sharing.**

**Supplementary table S4.** **Cribriform plate surface area data for individual specimens**. Identification, source, sex and morphological data for sample species. Abbreviations, AMNH: American Museum of Natural History. CMNH: Cleveland Museum of Natural History. DLC: Duke Lemur Center. DUPC: Duke University Primate Center. IZCAS: Institute of Zoology of the Chinese Academy of Sciences. LACM: Natural History Museum of Los Angeles County. LACMRLP: Rancho La Brea Tar Pits. MVZ: Museum of Vertebrate Zoology. SDSNH: San Diego Society of Natural History. UCLA: Dickey Collection at the University of California Los Angeles. UCLAEEB: UCLA Department of Ecology and Evolutionary Biology. USNM: National Museum of Natural History. UTO: University of Texas Austin. TMM: Texas Memorial Museum**.** \*The presence of a cribriform plate in the ethmoid bone of the bottlenose dolphin (*Tursiops truncatus*) could not be established in this study.

**Supplementary figure S5. Digitally quantifying CP surface area.** ***(a)***, Three-dimensional CP model from the French bulldog (*Canis familiaris*) is reconstructed from CT scan data in Mimics imaging program. ***(b)***, CP foramina are digitally filled to create a generalized continuous surface within the perforate region of the bone. ***(c)***, Surface area is isolated and calculated with imaging software 3-matic.

**Supplementary figure S6. Strong linear correlation between cribriform plate (CP) surface area (perforate area) and cumulative cross-sectional area of the CP foramina (log-log) (r2 = 0.91, *P <* 0.0001, n = 19*)*.** The more exacting metric of total CP foramina area, representing the imprint of olfactory axon bundles in the ethmoid bone, serves to validate CP surface area as a metric of relative olfactory innervation. CP surface area is the preferable metric for future studies, as it is easily quantifiable, even in skulls with some CP damage, such as fossils. CP surface area was measurable here in 26 sample species, while foramina area was measurable in only 19 species. Image on y axis: taken from figure S3. Images on the x axis: left, section of CP bone (red) with splines, (rings of coordinate points), assigned to the perimeters of several foramina in Mimics; right, imaging software Rhinoceros creates non-planar surfaces from the splines, and surface areas of foramina are calculated and tallied.

**Supplementary figure S7: 3D skull models showing marked reduction in CP morphology in taxa heavily reliant on non-olfactory sensory modalities. *(a)*,** CP loss viewed in nasal morphology of bottlenose dolphin (*Tursiops truncatus*), which uses echolocation. Pink: Single pair of foramina connecting ethmoid area of the nasal passage to the cranium. Inset, magnification of foramina. ***(b-c)***, Impact of orbit size on CP size constraints, contrasting the tarsier (*Tarsius syrichta*) and armadillo (*Dasypus novemcinctus*). ***(b)***, Tarsier, a visually-specialized nocturnal primate with enlarged, forward facing orbits, has reduced olfactory anatomy. Red: CP squeezed between convergent orbits. ***(c)*,** By contrast, the armadillo’s large CP (red) fills the space between small, laterally oriented, wide set orbits.

**Supplementary table S8: Morphological and genomic data for sample species.** Abbreviations: CP, cribriform plate; ORG, olfactory receptor gene. Body mass estimates are species means. Where sexual dimorphism was present, we considered the sex of individuals when deriving the species body mass. Individual dog breed body size estimates were averaged to calculate the mean body mass of the dog (*Canis familiaris*). References for body mass and ORG data listed below the table. For cribriform plate surface area data of individual specimens, see table S5.

**Supplementary table S9. Assembly statistics for genome assemblies from which olfactory receptor gene counts were extracted.** Abbreviations, BGI: Beijing Genomics Institute; BCM: Baylor College of Medicine; Broad: Broad Institute; ICGSC: International Cat Genome Sequencing Consortium; WU: Washington University. Sources of data: NCBI Assembly, University of California Santa Cruz Genome Browser, Genome Reference Consortium.

**Supplementary table S10. Summary statistics for all regressions.** Abbreviations: CP, Cribriform plate; RelCP, Relative cribriform plate size; ORG, Olfactory receptor genes; MIC, Maximal information coefficient; PGLS, Phylogenetic generalized least squares.

**Supplementary figure S11. Linear regressions in partitioned and non-partitioned data: RelCP vs absolute number of OR pseudogenes.** Among the six species with the largest pseudogene counts, the correlation is r2 = 0.744, *P =* 0.026, PGLS-r2 = 0.723, *P =*0.032 (red dashed line). There is no significant correlation among the 20 species with the lowest pseudogene counts. A significant linear correlation exists across the entire data, r2 = 0.36, *P =* 0.001, PGLS-r2 = 0.41, *P =*0.004 (gray dotted line).

**Supplementary figure S12. Estimating relative CP size (RelCP) to predict likely position of two non-genome species, the sabertooth cat (*Smilodon fatalis*) and the gray wolf (*Canis lupus*), on our olfactory scale. *(a)*,** Estimating RelCP of sabertooth cat (*Smilodon fatalis*) from its residualvalue in a regression of absolute CP surface area against body mass among sample species. ***(b)*,** *Smilodon*CP surface area is smaller for its body size than most of the ten living felid species for which CP data is known. ***(c)*,** In a regression of CP surface area vs. body size among the sample species, the gray wolf (*Canis lupus*) has a larger RelCP than the domestic dog (species mean of four dog breeds), predicting a larger ORG repertoire.

**Supplementary table S13. Sources and morphological data for felid species.** Museums and collections are as follows: FMNH: Field Museum of Natural History; LACM: Museum of Natural History of Los Angeles County; LACMRLP: Rancho La Brea Tar Pits; MMNH: James Ford Bell Museum University of Minnesota, Minneapolis; UCLAEEB: University of California Los Angeles Department of Ecology and Evolutionary Biology. aEstimated body masses are from [1] except for two species, *Felis catus* [9] and *Smilodon fatalis* [19] (see table S8 references).

**Supplementary figure S14. Adjusting ORG counts for low coverage genomes, or omitting low coverage species, improves correlation between RelCP and functional ORG number. *(a)*,** Plot from figure 2*b*; RelCP vs. functional ORGs (log10). Blue circles: species with low coverage (≤ 6x) genome assemblies (r2 = 0.76, *P* < 0.0001). ***(b)*,** Adjusted regression plot. Number of functional ORGs in low-coverage genomes is increased by 39.7%. Percent increase is derived by comparing the number of ORGs extracted from earlier, low-coverage draft genomes to the number from current ≥ 6x coverage assemblies, averaged over four available relevant cases (elephant, dog, cat, rabbit). Adjusted correlation: r2 = 0.84, *P* < 0.0001. Any increase in ORG count in low-coverage species strengthens the correlation, as all but two have relatively few ORGs for their RelCP. ***(c)*,** Omitting species with ≤6x genomes strengthens the correlation between RelCP and functional ORGs further (r2 = 0.89, *P* < 0.0001).

**Supplementary figure S15. High number of OR pseudogenes in species with large RelCP and large ORG repertoires. *(a)*,** Inversion of the axes from figure 3*a* showing that species with largest RelCP tend to have higher numbers of OR pseudogenes. ***(b)*,** A similar non-linear, dual pattern emerges when the dependent variable in figure 3*a* is changed from RelCP to number of functional ORG. Species with > ~500 pseudogenes tend to have the largest functional ORG repertoires.

**Supplementary figure S16. Skull pneumatization as possible correlate of large CP size; contrast between elephant and gorilla skulls shown in CT scan images and 3D skull models. *(a)*,** Coronal cross-section slice from CT scan of elephant (*Loxodonta africana*) skull showing ~250 mm pneumatized bone surrounding brain. Scale bar: 100 mm. ***(b)*,** Dorsal view of elephant skull model. Yellow line: locale of image in *(a)*. Scale bar: 100 mm. ***(c)*,** Coronal cross-section from CT scan of gorilla (*Gorilla gorilla*) skull; brain surrounded by non-pneumatized cortical bone. Scale bar: 40 mm. ***(d)*,** Dorsal view of gorilla skull model. Yellow line: locale of image in *(c)*. Red: CP.

**Supplementary figure S17. Ethmoturbinal complexity matches large RelCP in African elephant; contrast between turbinal-rich elephant skull and turbinal-depauperate rock hyrax skull shown in CT scan images and 3D skull models.** Ethmoturbinal bones, which carry the olfactory epithelium, are unusually expansive in the African elephant (*Loxodont africana*). Quantifying turbinal area is beyond the scope of this paper, but here we visually contrast homologous cross-sections through the nasal chamber at the anterior-most extension of the CP in the elephant and its closest living relative, the rock hyrax (*Procavia capensis*), which has a relatively small CP. ***(a)*,** Anterolateral view of elephant skull model. Orange plane: locale of image in image *(b)*. Scale bar: 100 mm. ***(b)*,** Coronal cross-section from CT scan of elephant nasal cavity. Scale bar: 20 mm. Blue: turbinal bones. Red: CP. ***(c)*,** Hyrax skull model. Scale bar: 10 mm. Orange plane: locale of image in (*d*). ***(d)*,** Coronal slice from CT scan of hyrax nasal cavity. Scale bar: 5 mm. Blue: turbinals. Red: CP.