429.24 Massive Enlargement of the Olfactory Bulbs of the Turkey Vulture (*Cathartes aura*)

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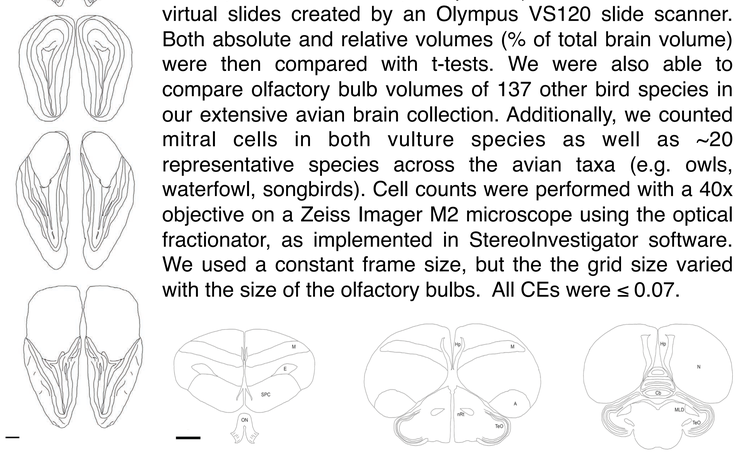
Background

Although olfaction remains largely understudied compared to vision and hearing in birds, there have been numerous studies over the past 40 years that have suggested that olfaction plays an important role in the ecology of many birds. The Turkey Vulture (*Cathartes aura*) and the Black Vulture (*Corygyps atratus*) are carrion feeders who are thought to differ in their use of visual and olfactory cues to locate carcasses. Based on behavioural observation, turkey vultures are thought to use olfactory cues extensively, whereas black vultures are thought to use vision almost exclusively. Here, we use quantitative neuroanatomy to determine the differences between the two species in olfactory and visual regions of the brain that correlate with the noted behavioural differences. We also quantify mitral cell counts within the olfactory bulbs of many avian species to determine a relationship between bulb volume and cell number.

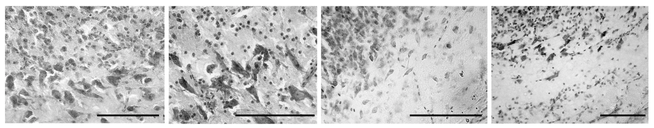
Close-up photos of a black vulture (left) and turkey vulture (right). Note that the turkey vulture has nostrils that are more distal and larger than that of the black vulture.

Methods

Six specimens (3 of each species) were collected in Tennessee, USA. The heads were immersion fixed in paraformaldehyde and the brains extracted, sectioned in the coronal plane, and stained for Nissl substance. The volumes of the olfactory bulbs, as well as three visual regions (optic tectum, nucleus rotundus, entopallium) were measured from virtual slides created by an Olympus VS120 slide scanner. Both absolute and relative volumes (% of total brain volume) were then compared with t-tests. We were also able to compare olfactory bulb volumes of 137 other bird species in our extensive avian brain collection. Additionally, we counted mitral cells in both vulture species as well as ~20 representative species across the avian taxa (e.g. owls, waterfowl, songbirds). Cell counts were performed with a 40x objective on a Zeiss Imager M2 microscope using the optical fractionator, as implemented in StereoInvestigator software. We used a constant frame size, but the the grid size varied with the size of the olfactory bulbs. All CEs were ≤ 0.07.



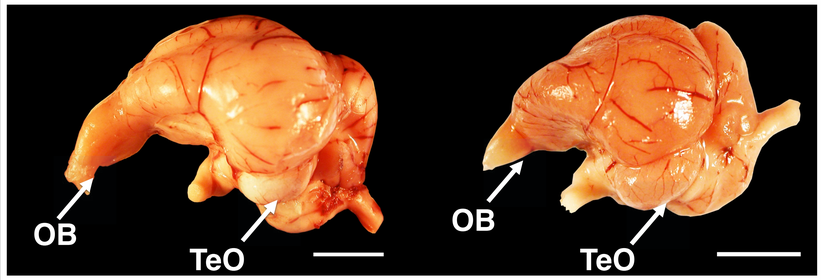
Above and on left: line drawings of coronal sections through a turkey vulture brain. Layered olfactory bulbs are shown vertically, whereas the bottom row shows several brain regions, including the visual regions measured in this study. Abbreviated brain regions are as follows: A = arcopallium, Cb = cerebellum, Hp = hippocampus, M = mesopallium, MLD = nucleus mesencephalicus lateralis, pars dorsalis, N = nidopallium, nRt = nucleus rotundus, ON = optic nerve, SPC = striatopallidal complex, TeO = optic tectum. Scale bars = 5 mm.

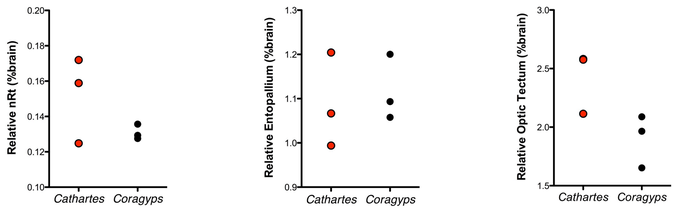


Above: photomicrographs of mitral cells iin the following species (from left to right): black vulture, turkey vulture, grey catbird (*Dumetella carolinensis*) and ruffed grouse (*Bonasa umbellus*). All scale bars = 100 microns.

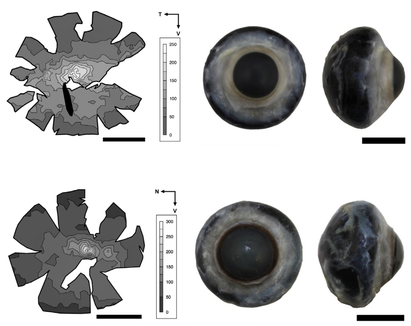
Comparisons Between Vulture Species

Marked differences in brain morphology were readily apparent between the two vulture species upon dissection. The turkey vulture (left) appears to have much larger olfactory bulbs (OB) and smaller optic tectum (TeO) than the black vulture (right). Further, the turkey vultures had significantly smaller brains than black vultures overall (t = 5.26, p = 0.03). Scale bars = 10 mm.

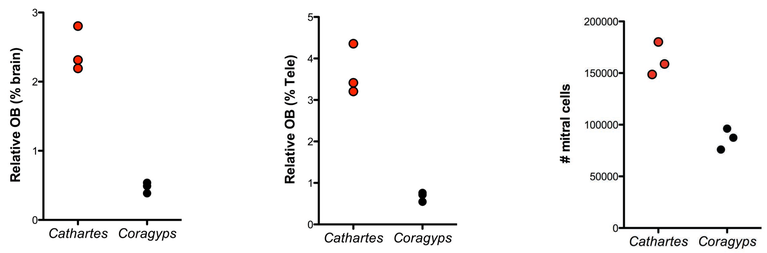




The two species did not differ in the relative size of any of the three visual regions that we measured: nucleus rotundus (nRt) (p = 0.21) , entopallium (p = 0.72), or optic tectum (p = 0.06).

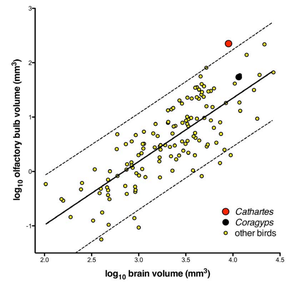


The lack of significant differences in visual nuclei paralleled a recent study of eye morphology and retinal topography (Lisney et al. 2013 Anat Rec 296: 1954-1970), in which no significant differences were found in retinal topography or retinal ganglion cells counts. The two species only differed in eye shape; the black vulture (bottom left) has a relatively larger cornea than the turkey vulture (top left).

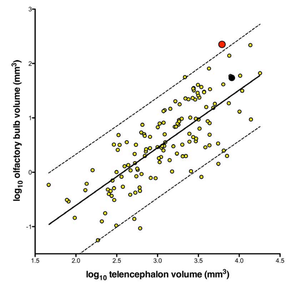


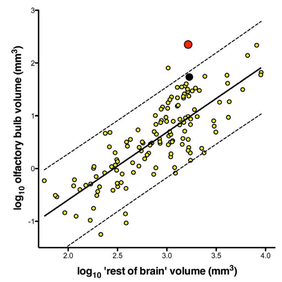
The turkey vulture has significantly larger olfactory bulbs (OB) than the black vulture, relative to both overall brain size (t = 10.22, p = 0.0005) and telencephalon size (t = 8.29, p = 0.001). Overall, turkey vultures have OBs that are **4-5x larger** than that of black vultures. Similarly, turkey vultures have significantly more (**1.5-2x more**) mitral cells than black vultures (t = 6.91, p = 0.002)

Comparisons With Other Species



Scatterplots of olfactory bulb volumes against overall brain volume, telencephalon volume, and 'rest of brain' volume (diencephalon, mesencephalon, pons and medulla). The solid line is the least-squares linear regression line and the dotted lines represent the 95% prediction interval for all 137 species in this data set. In all three scatterplots, the turkey vulture has much larger olfactory bulbs relative to the scaling variable. In fact, the turkey vulture is the only significant outlier across analyses with the brown kiwi (*Apteryx australis*) being a close second.

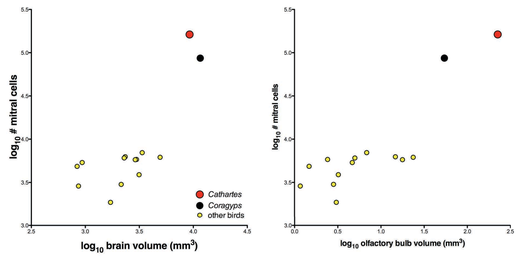




Brain volume:
y = 1.167x – 3.317

Telencephalon volume:
y = 1.060x – 2.729

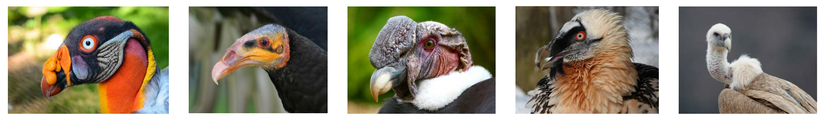
'rest of brain' volume:
y = 1.281x – 3.156



No significant relationships were detected between the number of mitral cells and brain or olfactory bulb volumes. Nevertheless, both vulture species had more mitral cells in relative and absolute terms, than the other 12 species measured thus far.

Conclusions

- **The two vulture species do not differ in the relative size of the visual regions measured in the brain.**
- **Turkey vultures have massively enlarged olfactory bulbs compared to black vultures and all other avian species thus far examined.**
- **Future studies will test olfactory acuity between black and turkey vultures and examine the neuroanatomy of other vulture species.**



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