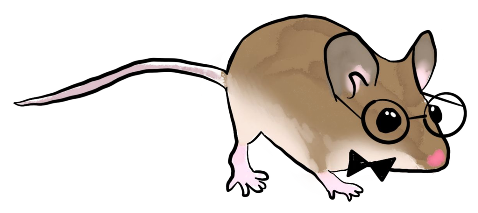
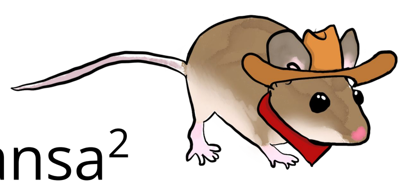
Country Mice and City Mice: High-resolution μCT Scans Reveals City Mice are, In Fact, Brainier



(Rodentia:Muridae)



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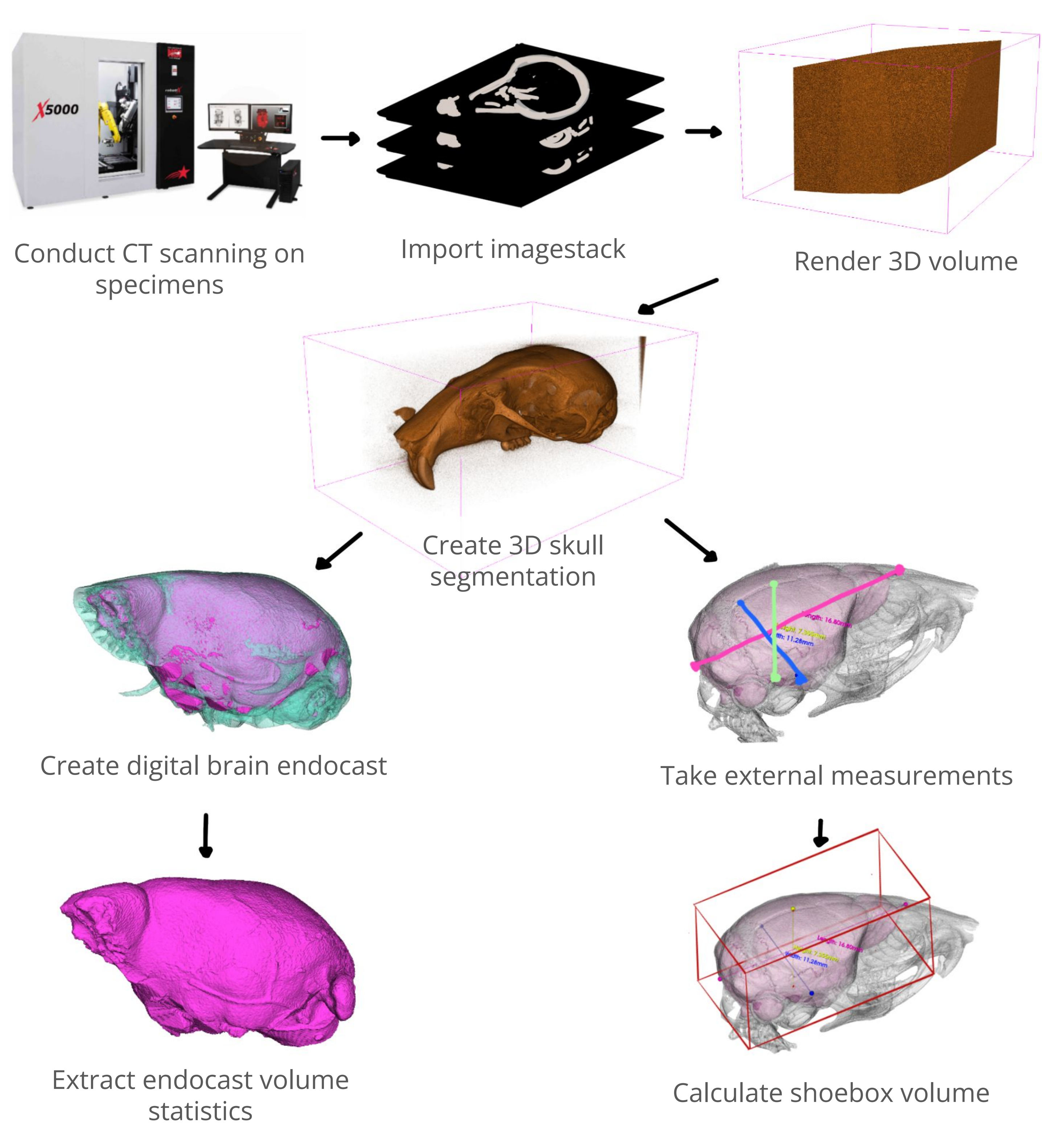
Introduction

Urban environments are novel and challenging environments for most wildlife species, but many successfully adapt and thrive through behavioral and physiological adaptations to urban settings [1]. In Minnesota, white-footed mice (*Peromyscus leucopus*) from urban areas show **larger cranial capacities** than their rural counterparts [2].

Previous studies estimated brain size using external skull measurements, but their accuracy in predicting actual brain volume remains unclear. Our study uses **μCT scans** to create digital **brain endocasts** of museum specimens, providing direct measurements of endocranial volume. We aim to 1.) assess the predictive power of external measurements for estimating brain size and 2.) re-examine urban–rural brain size differences using these improved estimates.

Method

Figure 1. Endocast Reconstruction Workflow



Following this protocol (Fig. 1), we generated 28 digital endocasts, representing a species complex dataset (*P. labecula* [n = 9], *P. gambelli* [n = 1], *P. maniculatus* [n = 4], *P. melanotis* [n = 1], *P. sonoriensis* [n = 13]).

Estimating Brain Size from External Neurocranial Measurements

Table 1. Model Comparison for Predicting Power of Neurocranium Measurements

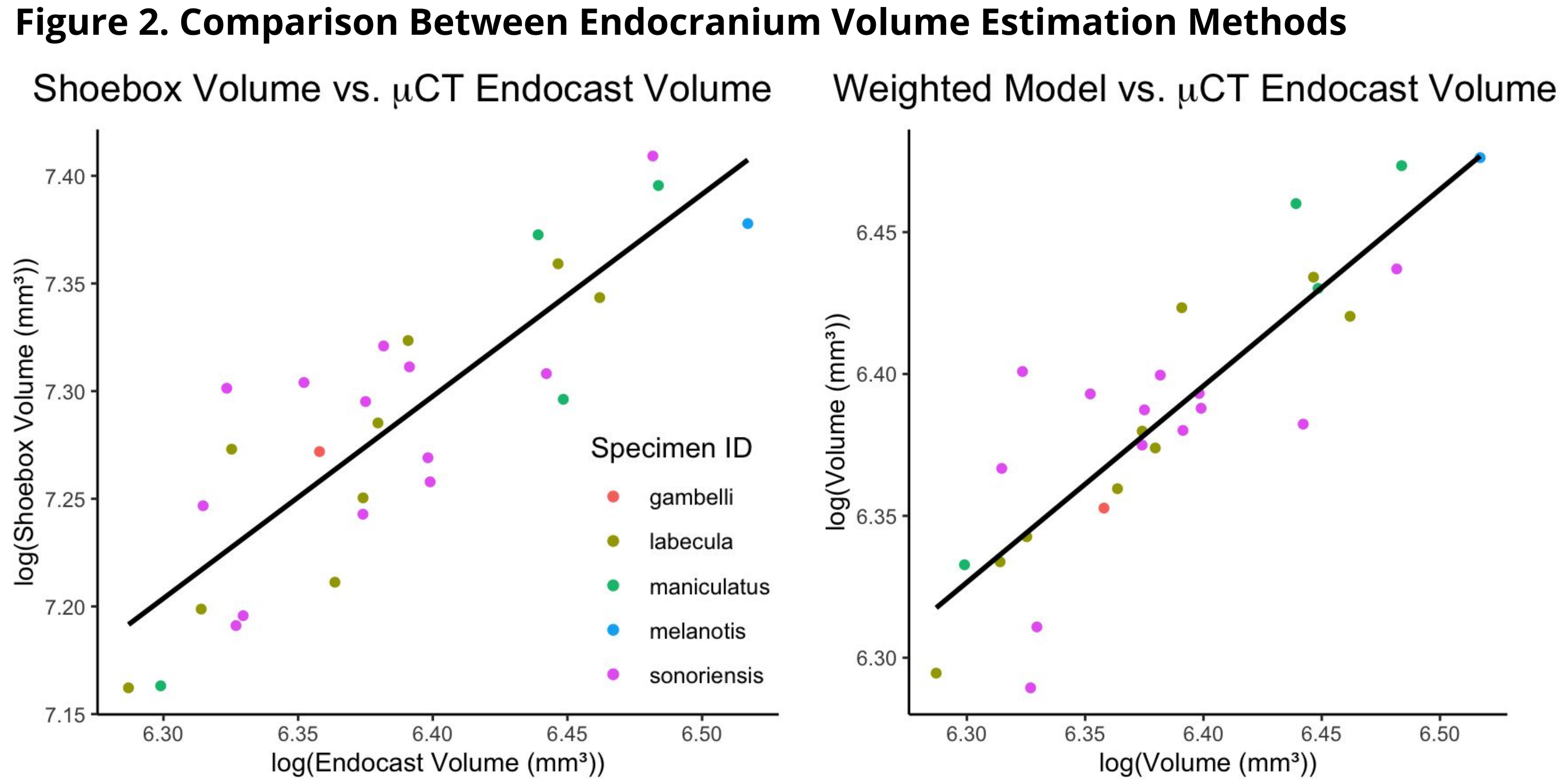
Model	R^2	ESS	K	AICc	Δi	wi
Height, width	0.755	0.076	4	-107.899	0	0.5813
Length, width, height	0.775	0.078	5	-107.228	0.671	0.4156
Height, length	0.621	0.062	4	-95.619	12.28	0.0013
Length, width	0.605	0.061	4	-94.515	13.384	0.0007
Width	0.572	0.057	3	-94.969	12.93	0.0009
Height	0.525	0.053	3	-92.084	15.815	0.0002
Length	0.253	0.025	3	-79.41	28.489	3.78e-0

We assessed how well external cranial measurements predicted brain volume using a linear modeling approach. The **model including only neurocranial height and width performed best (R^2 = 0.755)**, while the inclusion of length did not significantly improve fit. Based on the relative AIC weights of each model, we constructed a weighted average model that combines the contributions of individual slopes according to their model support.

$$ln(Endocast\ Volume) = 0.46 + 0.45 ln(Height) + 0.17 ln(Length) + 0.18 ln(Width)$$

We applied this model in a re-analysis of the original dataset that showed differences between urban and rural mouse brains[2], and compared our predictions to their original external measurement approach (length × width × height), hereafter referred to as the "shoebox" method.

Figure 2. Comparison Between Endocranium Volume Estimation Methods

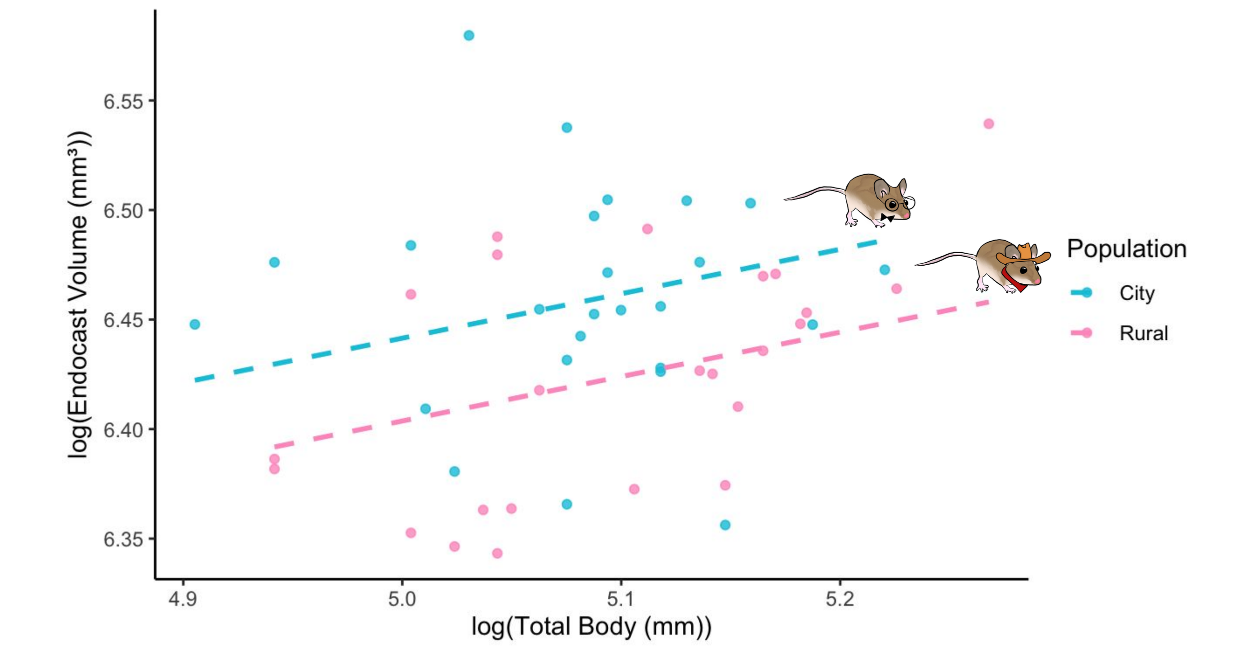


While the shoebox method provides accurate prediction of neurocranium volume (R^2=0.719, $p < 0.001$), **our model demonstrates greater predictive power** in explaining variation in endocast volume (R^2=0.745, $p<0.001$).

Investigating Cause of Urban & Rural Brain Size Differences

Figure 3. Endocast Volume as a Function of Body Size Across Populations

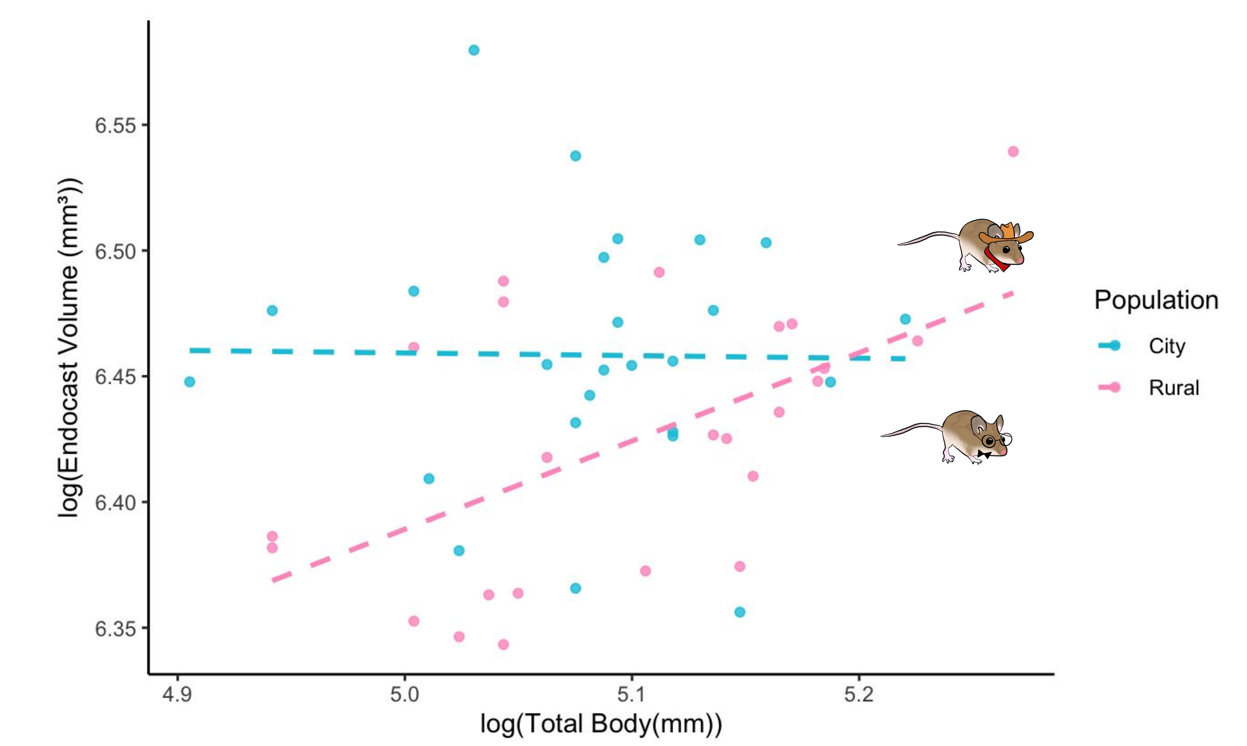
log(Model Predicted Endocast Volume) ~ Population + log(Body Size)



We used our estimate of brain size to revisit the findings of Snell-Rood and Wick[2]. We confirmed that there is a **positive relationship** between body size and brain size (R^2 = 0.152) and that urban mice have significantly larger brains than rural mice (p = 0.012).

Figure 4. Modeling Population-Specific Allometry: Interaction Effects

log(Model Predicted Endocast Volume) ~ Population × log(Body Size)



Next, we tested how allowing for an interaction between body size and population type affected our model. **This model explained more variance** (R^2 = 0.201), though adding an interaction effect did not significantly change the model fit (p = 0.056). This suggests **that the positive correlation between body size and brain size is only true for rural mice, and the two populations follow different allometric trajectories.**

This is consistent with the expensive tissue hypothesis, which proposes that energetic trade-offs constrain investment in metabolically costly organs like the brain. In **urban environments with abundant resources, mice are able to allocate more energy into brain development** whereas in rural mice, the rate brain growth is constrained by rate of overall growth.

References

[1] Sol, D. 2009. The Cognitive-Buffer Hypothesis for the Evolution of Large Brains. Pages 111–134 Cognitive Ecology II. University of Chicago Press.

[2] Snell-Rood, E. C., and N. Wick. 2013. Anthropogenic environments exert variable selection on cranial capacity in mammals. Proceedings of the Royal Society B: Biological Sciences 280:20131384.