

The case of the missing body parts: computational approaches to the fossil record

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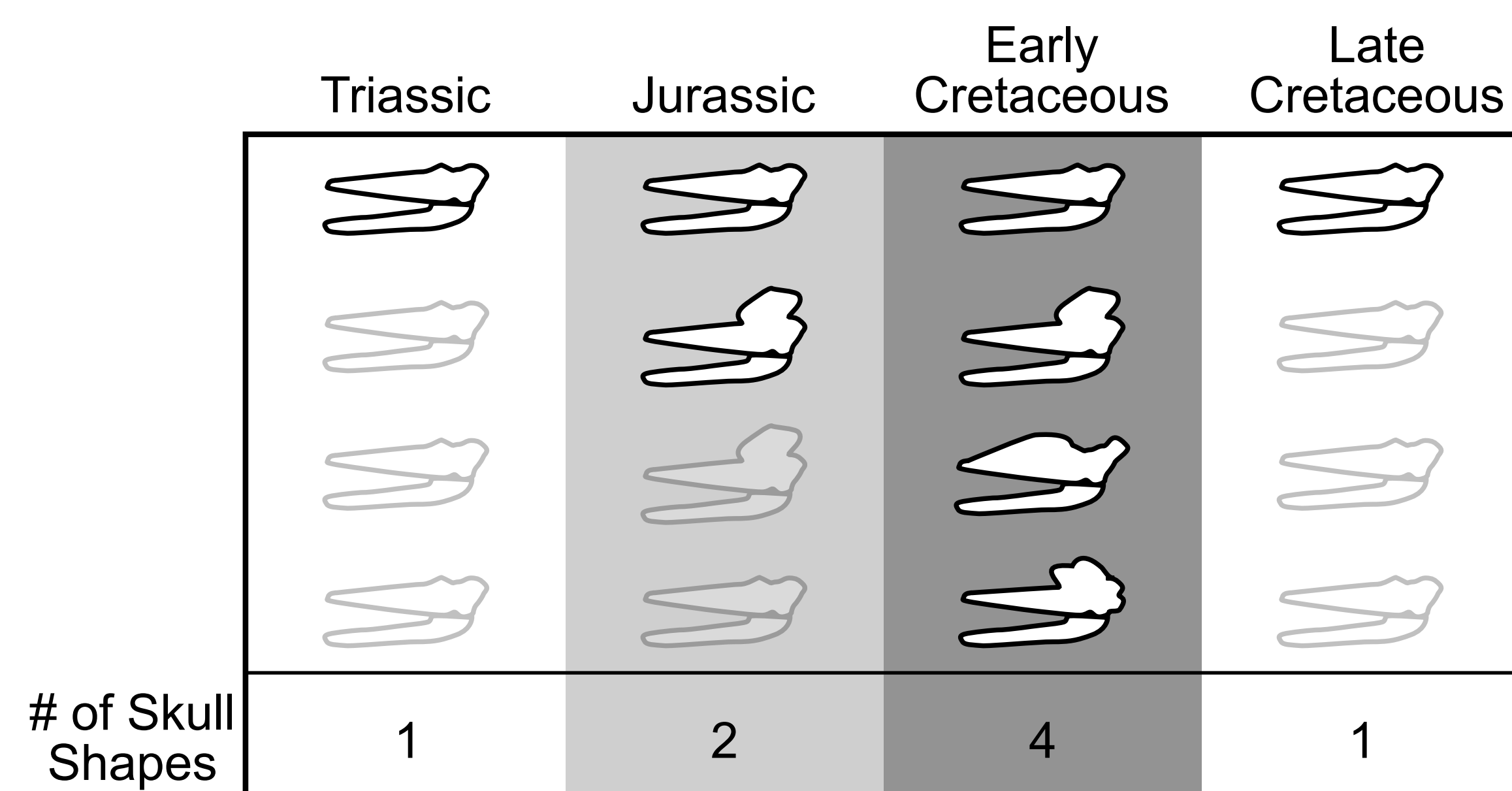
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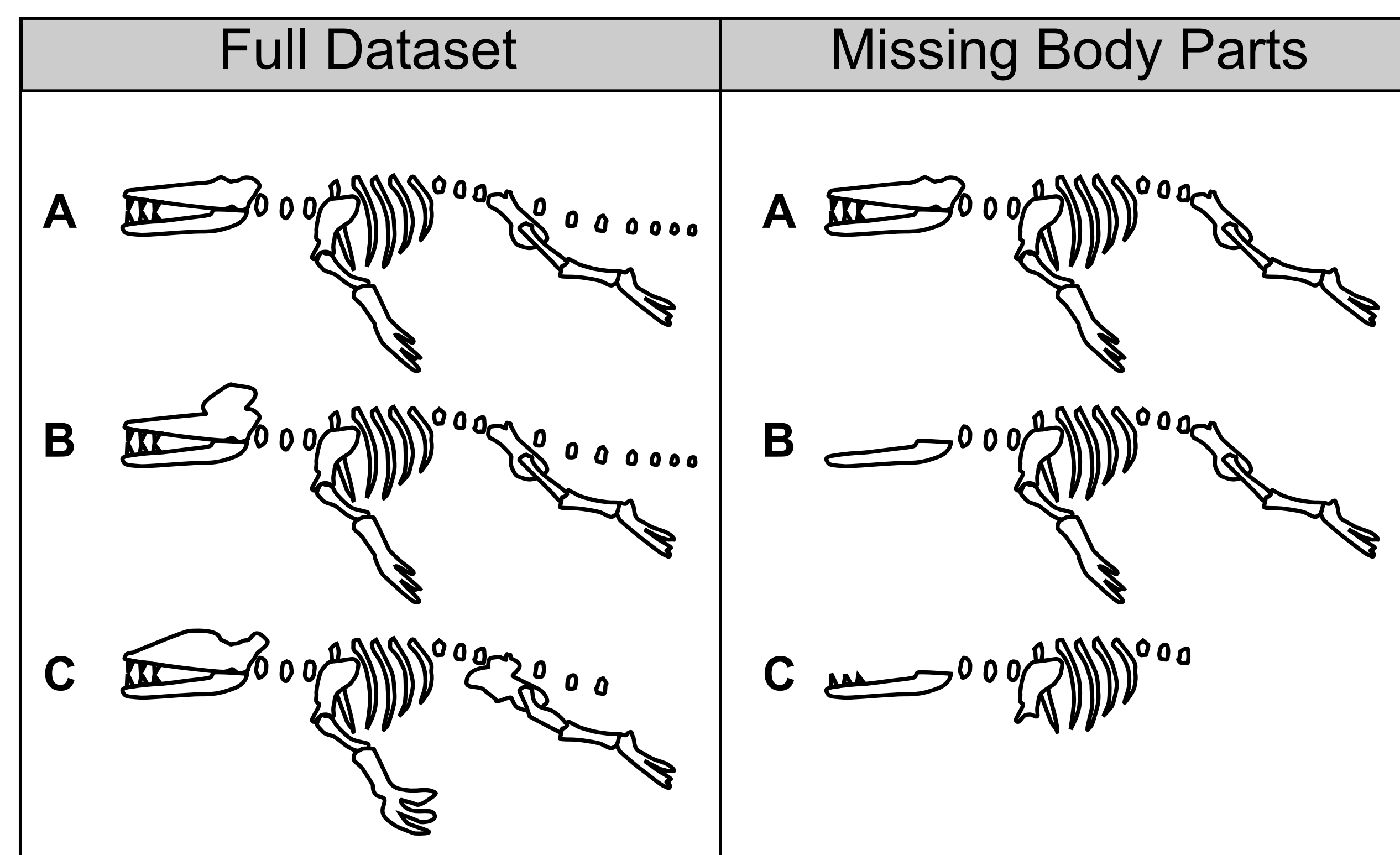
Differences in the shapes of body parts show patterns of biodiversity over evolutionary time.



Disparity is a measure of biodiversity that quantifies differences in the shapes of body parts. In this example, the number of skull shapes suggest an increase in biodiversity in the early Cretaceous and a decline in the late Cretaceous.

Missing body parts make accurately measuring disparity difficult.

How many differences in body parts can you count among A, B, and C?



When body parts are missing, disparity is likely underestimated. The right column results in lower disparity than the left column.

Fossil datasets contain taxa with many missing body parts.



Mammals¹
53% missing



Arthropods²
79% missing



Birds³
81% missing

Questions

1) How many body parts can be missing while still yielding correct conclusions about disparity?

2) Does normalizing the amount of missing body parts affect our understanding of fossil biodiversity?

We designed a data-loss algorithm that acts like a carnival wheel, and incorporates information from fossil datasets to simulate missing body parts.

The algorithm learns the relationships of missing body parts from published fossil datasets.

Spinning the wheel determines which body part to "lose" in the simulation.

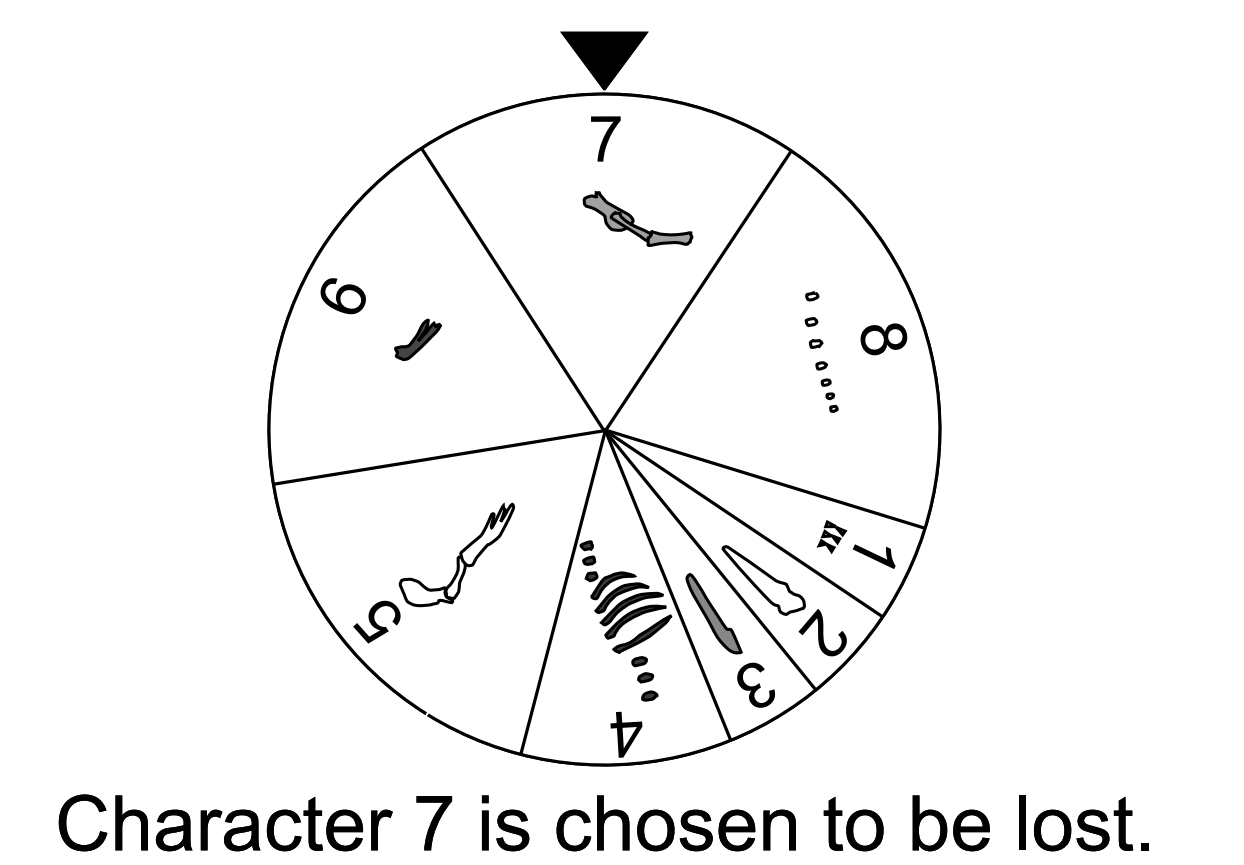
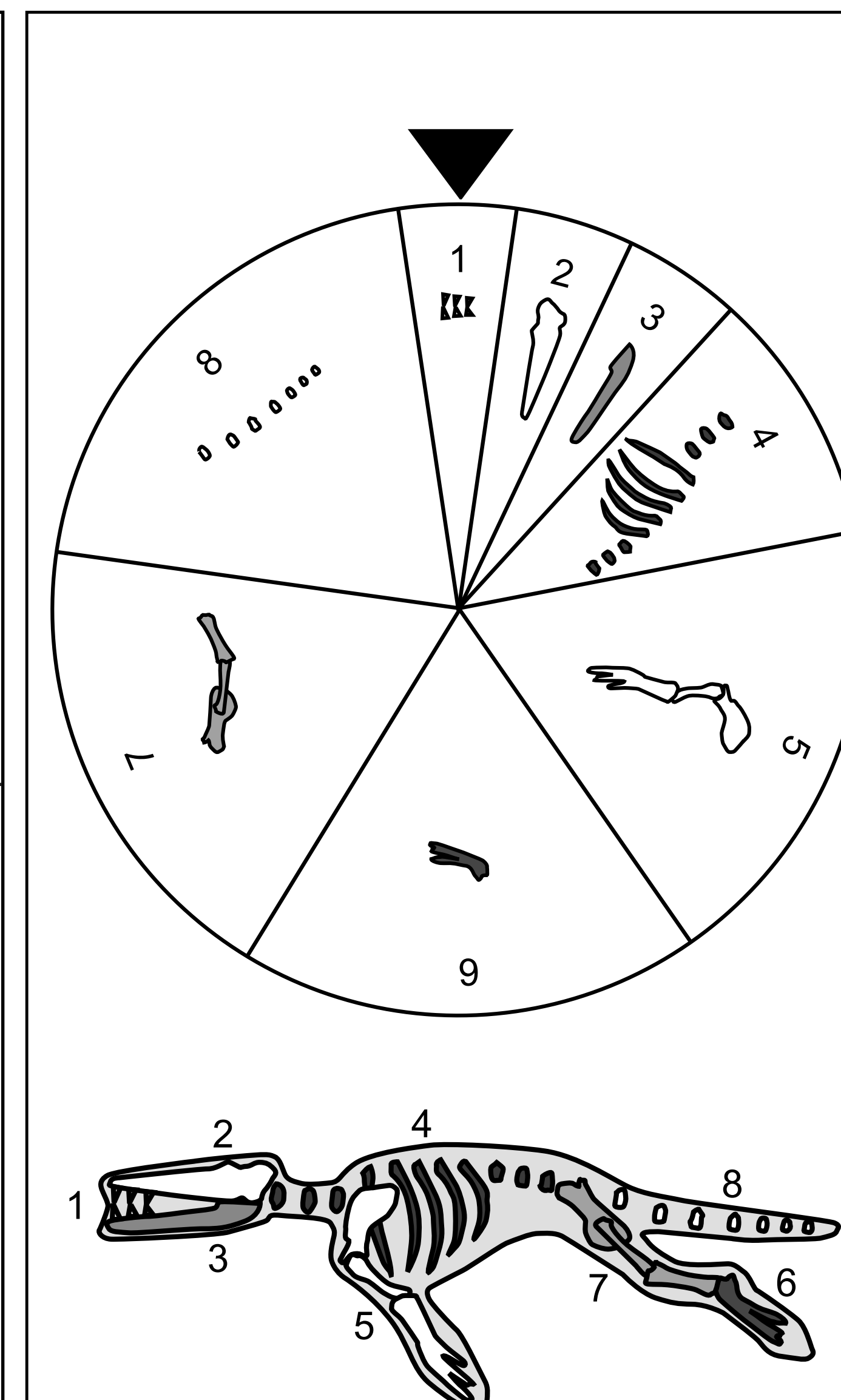
Wedge sizes are updated using information in the fossil dataset.

Body Part	Fraction Missing
1	0.10
2	0.10
3	0.10
4	0.25
5	0.75
6	0.75
7	0.75
8	0.75

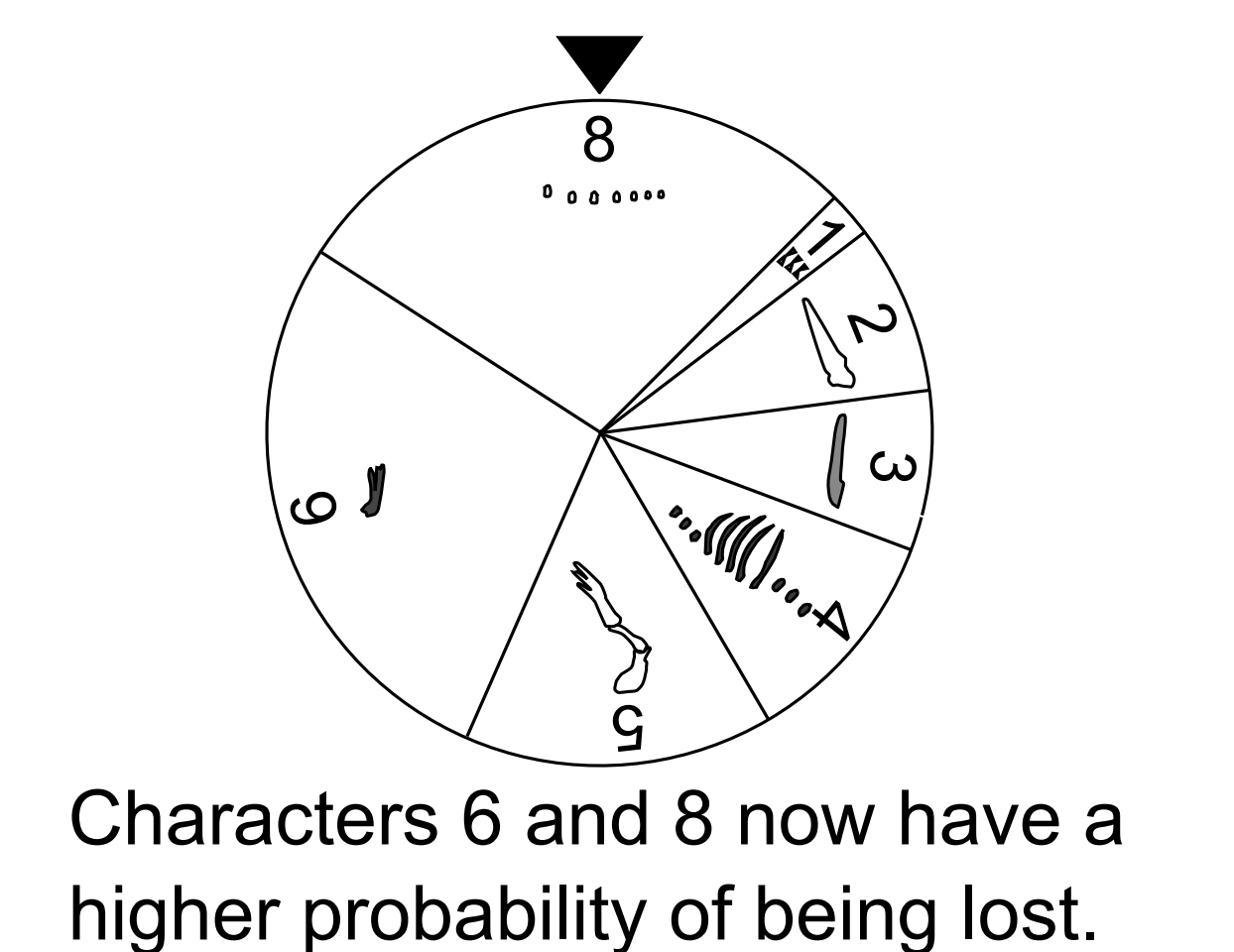
Initial wedge sizes of the carnival wheel are determined by the fraction of taxa missing that body part.

Morphological Character	1	2	3	4	5	6	7	8
1		0.25	0.25	0.10	0.10	0.10	0.10	0.10
2			0.90	0.25	0.25	0.50	0.50	0.75
3				0.10	0.50	0.50	0.50	0.10
4					0.25	0.50	0.25	0.50
5						0.75	0.50	0.75
6							0.90	0.75
7								0.90
8								

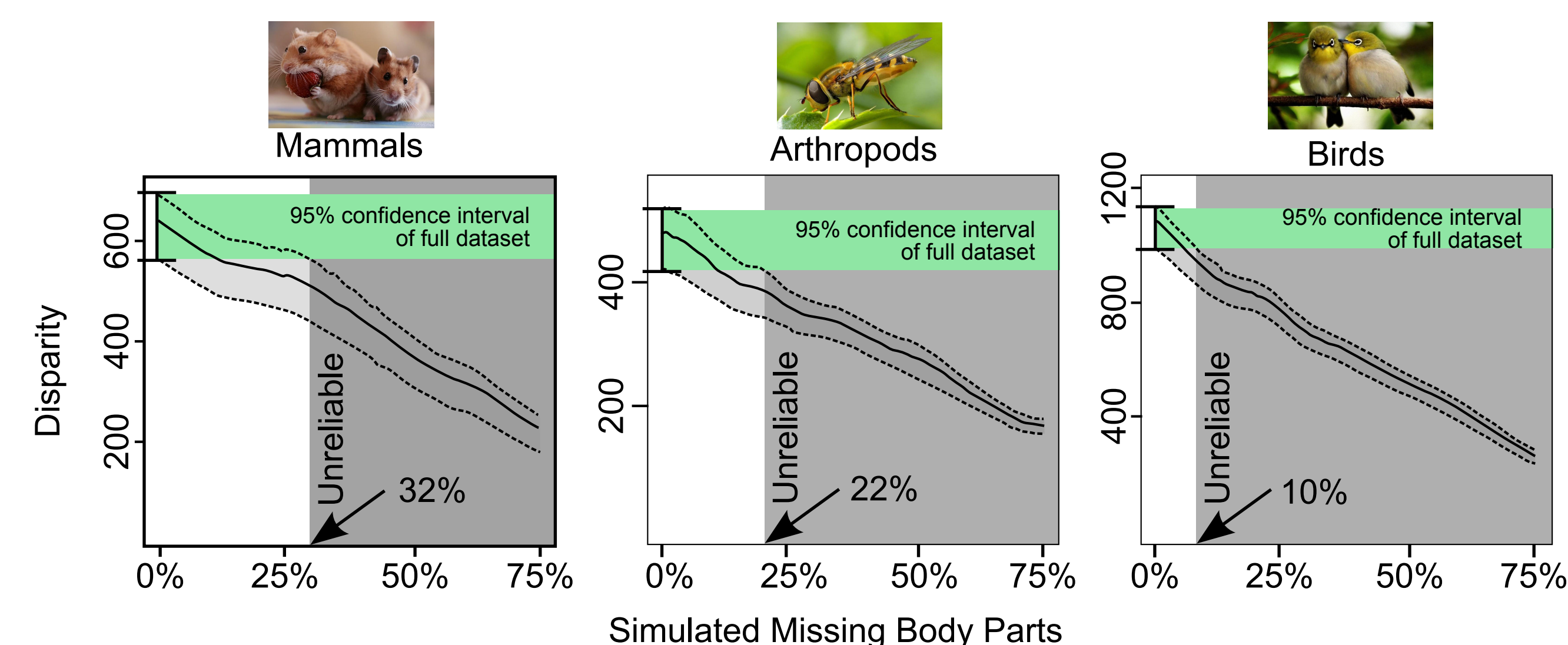
In subsequent "spins" of the wheel, wedge size is adjusted by incorporating correlations of missing body parts.



In the fossil dataset, characters 6 and 8 are likely lost in concert with character 7.



Degrading full datasets reveals that fossil disparity is significantly underestimated.

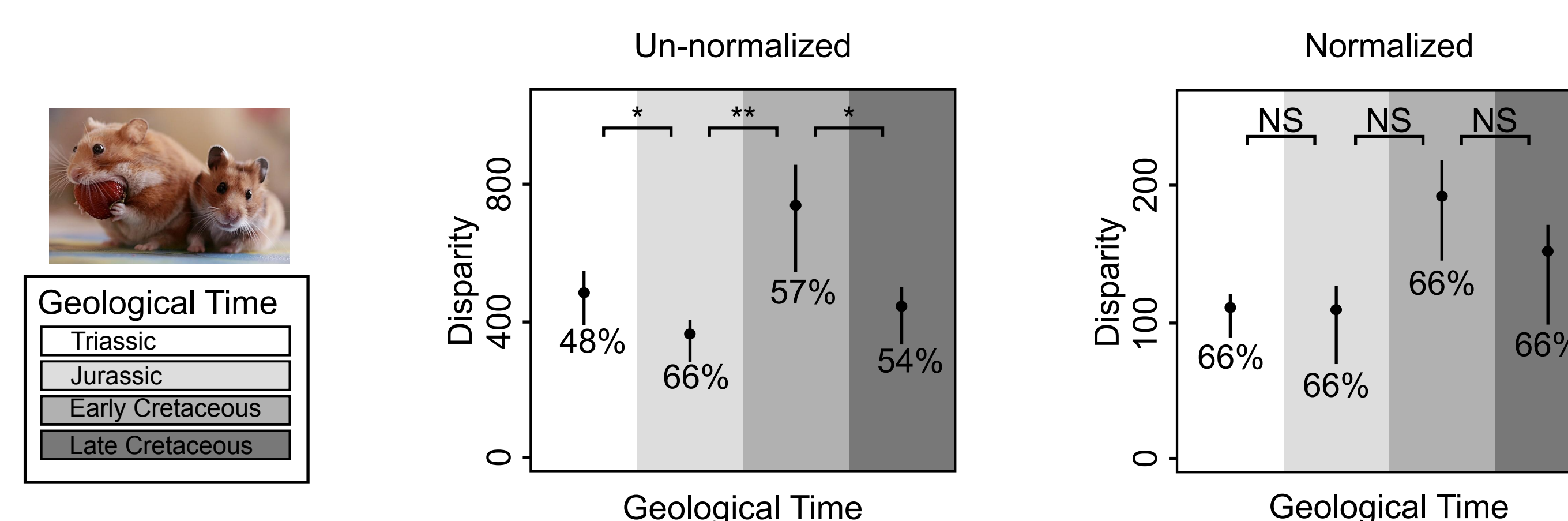


Grey regions yield incorrect conclusions about disparity. The mammal dataset is the most robust to missing body parts.

Conclusions

- The amount of missing body parts in fossil datasets is likely to significantly underrepresent disparity.
- Variation in the number of missing body parts can result in misleading patterns of biodiversity over evolutionary time scales.
- Our "carnival wheel" algorithm is a computation tool that researchers can use to identify the effects of missing body parts on disparity measures, and is especially relevant in fossil datasets.

Normalizing for missing body parts shows no significant changes in mammal disparity over time.



Significant changes in disparity over geological time are artifacts of differing amounts of missing body parts in each time bin.

Acknowledgements

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