Scaling of Sensory Information Intake in Organisms

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ABSTRACT

The metabolic resources required by organisms are known to scale with their mass raised to the $3/4$ power. Like energy and nutrients, information about the environment is also a necessary resource for life. However, little attention has been placed on how the capacity to absorb information scales with size. We have taken steps toward answering this question by a) synthesizing data on sensory capacity from multiple organisms to try and answer the question empirically and b) exploring theoretical considerations that might allow us to deduce the scaling laws from first principles. We hypothesize that as organisms increase in size and complexity, their sensory capacity per unit mass decreases, owing to the fact that less total information is needed if it can be processed in a more sophisticated manner. Preliminary results, both theoretical and empirical, are supportive of this claim. In particular, we derive a fundamental bound on the sensory capacity of a spherical cell arising from the heat it dissipates, which turns out to be a linear function of the cell radius r. As the mass of a cell scales as r^3, our bound implies that the maximum achievable channel capacity per unit mass decreases with the size of the organism. We also investigate the hypothesis that organisms at all scales devote a fixed fraction of their metabolic rate to gathering sensory information, and find tentative support for this claim.
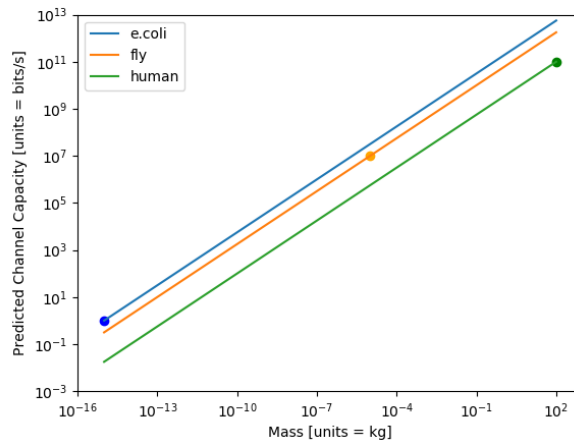
Figure 1. Predicting the scaling of information intake under the assumption that organisms devote a fixed fraction of their metabolic rate to information gathering. Note that flies fall below the extrapolated line for E. coli and that humans fall below the extrapolated line for flies.