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On Gray's paradox and efficiency measures for swimming[1] RAHUL
BALE, MAX HAO, AMNEET BHALLA, NEELESH PATANKAR, Northwestern
University
— In 1936 Gray reported that the "drag" power of dolphins was substan-
tially larger than the estimates of muscle power. We revisit this "paradox" in the
context of undulatory swimming. We consider larval zebrafish as a model system.
We question the basic premise of comparing drag power to muscle power. There
are two reasons. First, we recognize that it may not be possible decompose the
net force on an undulatory swimmer into drag and thrust. If it becomes possible,
as we show in our case, the drag power, which represents the work done on the
fluid due to motion in the swimming direction, is exactly balanced by the thrust
power, which represents the work done by the fluid. Thus, the total power in the
swimming direction, computed in this way, is zero. Second, we show that most of
the muscle energy is dissipated in causing the lateral motion of the body - not in
overcoming the "drag" in the swimming direction. This will be shown based on a
power balance equation. Thus, we argue that efficiency measures, that relate the
drag power to muscle power, or the Froude efficiency, are not recommended. Instead
non-dimensional cost-of-transport could be a useful measure to compare efficiencies
of organisms at different scales.

Neelesh Patankar
Northwestern University

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