STUDYING THE EFFECTS OF STRONG MAGNETIC FIELDS AND FORCES ON THE SWIMMING OF PROTOZOA

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Introduction

The swimming speed of Paramecium, a single cell protozoan, varies with its orientation relative to the gravity vector [1]. This phenomenon is remarkable as it suggests that the cell senses forces comparable to its apparent weight, which is only ~10 pN. To aid investigations of potential mechanisms, we have developed a method that uses magnetic forces to simulate variable gravity environments ranging from 10g to -8g, where g is earth’s gravity. We have obtained evidence that paramecia regulate their swimming in magnetically simulated hyper-gravity as they do in the hyper-gravity of a centrifuge.

Experimental

In an inhomogeneous magnetic field, $B$, the apparent weight per volume of a cell in solution changes from its normal value, $\Delta\rho g$, to $\Delta\rho g = \Delta\rho - \Delta\chi \frac{\mu_0}{B} B'$, where $\Delta\rho$ and $\Delta\chi$ give the differences between the cell and solution densities and magnetic susceptibilities, respectively. $B'$ is the vertical magnetic field gradient. To access a substantial range of simulated gravities, we boost $\Delta\chi$ by doping the solution with paramagnetic Gd-DTPA and employ the resistive magnet in Cell 5 ($B \leq 31$ T and $BB' \leq 4728$ T$^2$ m$^{-1}$). Other experimental details are published elsewhere [2].

Results and Discussion

In simulated 0g, the upward and downward swimming (Fig. 1A) speed distributions of paramecia lie nearly atop one another (Fig. 1B). Increasing $\tilde{g}$ to 4g (Fig. 1C), causes the upward swimmers, who must fight sedimentation, to swim more slowly and the downward swimmers, who swim with sedimentation, to swim faster. The expected shifts in the distributions for a simple passive response to the enhanced sedimentation force are indicated by the solid lines. The data suggest, however, that paramecia oppose the sedimentation force as the distributions shift by less than the passive prediction. Thus, it appears that magnetically simulated gravity elicits a physiological (active) response similar to that elicited by centrifugation (1).

Conclusions

Our results suggest that magnetic forces can be applied to simulate variable gravity environments for the study of gravity-responses of swimming microorganisms. This approach has potential for earth bound investigations of the changes in cell growth and signaling [3] and plant growth [4] induced by gravity.

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References