Phytoplankton in a turbulent ocean

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Phytoplankton are among the ocean's most important organisms and it has long been recognized that ocean turbulence is a primary determinant of their fitness and species succession. Recent studies have shown how turbulence can lead to the formation of phytoplankton patches and impact phytoplankton's vertical migration rates [1]. While these studies revealed passive interactions between fluid flow and phenotypic traits (mass distribution, motility, morphology), much less is known on whether phytoplankton can actively respond to turbulence. We present recent results that illustrate a striking behavioral response of a population of phytoplankton cells to turbulence-like cues, wherein cells altered their direction of migration within minutes upon exposure to overturning events modeling those experienced by cells in a turbulent ocean. Quantitative image analysis at the single-cell level showed that this behavioral switch was accompanied by a rapid morphological change at the sub-micrometer scale, and a mathematical model of the cell's mechanical stability confirms that this shape change can flip the swimming direction and ultimately induce downward migration. Concomitant observations of enhanced cellular stress upon overturning suggest that the observed behavior is an escape response from turbulent microzones, akin to bet-hedging, and can expand the hydrodynamic niche of motile phytoplankton [2].

[1] W.M. Durham and R. Stocker, Ann. Rev. Mar. Sci., 4, 177-207 (2012).

[2] A. Sengupta, F. Carrara, and R. Stocker, in preparation