Navigation at the micro-scale: Swimming, steering, synchronization of biological micro-swimmers

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Single biological cells can swim in a liquid, harnessing mechanical forces generated by ten-thousands of nano-scale motor proteins. Their swimming is controlled by chemical and mechanical signals for directed navigation. A prime example is represented by swimming sperm cells, which are guided by concentration gradients of signaling molecules towards the egg. Here, I review a unique navigation strategy along helical paths employed by sperm cells of external fertilizers, which is remarkably robust in the presence of sensing noise [1]. In a second part, I will present a biological example of "embodiment control" in a biological microswimmer, where interaction with the physical environment results in a coordinated swimming gait by a mechanical self-stabilization mechanism [2]. Ultimately, navigation principle invented by nature can be exploited for the design of intelligent artificial microswimmers.

Figure 1. Artistic representation of "The Computational Sperm Cell", navigating in response to chemical cues toward the egg.

References

[1] J.F. Jikeli et al.: Sperm navigation along helical paths in 3D chemoattractant landscapes, Nature Communications 6, 2015

[2] G.S. Klindt, C. Ruloff, C. Wagner, B.M. Friedrich, Load-response of the flagellar beat, Phys. Rev. Lett. 117, 2016

Figures