Neuromechanics of unsteady locomotion in fishes

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1 Abstract

Unlike machines, animals move through their world using flexible appendages, which bend due to internal muscle and body forces, but also due to forces from the environment (Fig. 1). Fishes, in particular, must cope with fluid dynamic forces that not only resist their overall swimming movements but also may have unsteady flow patterns, vortices, and turbulence. In my lab, we study how fishes, with their very flexible bodies, are able to move effectively and compensate for unexpected perturbations. I will first discuss some computational results, showing that steady swimming speed and acceleration performance can both be optimized by changing the passive body stiffness, but that optimal stiffness are different for each behavior. Fish must be able to swim steadily and conserve energy, but they must also be able to accelerate to escape predators or capture prey. How can they reconcile these conflicting demands? One possibility is that they could actively stiffen their bodies by co-activating muscle on both sides of their bodies, increasing the effective stiffness for better acceleration performance. I will discuss some recent experimental results, showing that bluegill sunfish may indeed use this strategy when accelerating. Finally, I will describe how the nervous system interacts with the mechanical properties of the body and muscle to help fish compensate for unexpected perturbations. We have been developing a new technique for quantifying how the nervous system and body respond to perturbations during rhythmic movements, like swimming. Based on these results, we have found that the effective stiffness and damping of muscle varies during the swimming cycle, and that fish can alter both the magnitude and timing of peak stiffness and damping. Together, these results are starting to produce an integrative understanding of how fish swim effectively in their complex, turbulent environment.

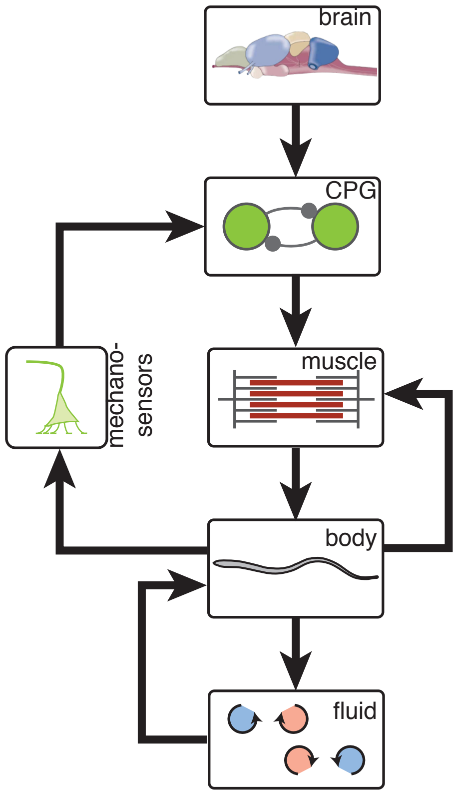

Figure 1: Schematic of the multiple nested neural and mechanical feedback loops used when a fish swims.