Talk 101
Dynamics of Multifunctionality
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Biological systems are often multifunctional; i.e., the same peripheral structures can be used for multiple functions. For example, the human leg can be used for both forward and backward locomotion. What are the dynamical principles underlying multifunctionality? The feeding apparatus (the buccal mass) of *Aplysia californica* is multifunctional. It generates three feeding responses: biting (an attempt to grasp food), swallowing (ingestion of grasped food), and rejection (expelling inedible material). Because of the small mass and slow movement of the buccal mass, inertial forces can be neglected. As a consequence, feeding behaviors can be understood by predicting the positions at which muscular forces balance (i.e., equilibrium points). These equilibrium points are determined by muscle activation and grasper shape. Activating the I2 muscle generates a stable equilibrium point corresponding to protraction. In contrast, the I1/I3 muscle generates two stable equilibrium points (at full protraction and full retraction) and an unstable equilibrium point in between. In *swallowing*, I2's activation moves the grasper towards a protracted equilibrium point, but I2's activation shuts off while the grasper is still within the basin of attraction of I1/I3's retraction equilibrium point, so that I1/I3 activation retracts the grasper. In *biting*, I2 moves the grasper much further towards a protracted equilibrium point. The grasper is now within the basin of attraction of the I1/I3 protraction equilibrium point so that I1/I3 activation protracts the grasper. Once the grasper closes and changes shape, the unstable equilibrium point vanishes so that the grasper is in the basin of attraction of I1/I3's retraction equilibrium point, and therefore the grasper retracts. In *rejection*, the grasper closes during protraction, shifting I2's equilibrium point more anteriorly, so that I2 can induce a larger protraction. The hinge initiates retraction as the grasper opens, and I1/I3 is activated only once the grasper is in the basin of attraction of I1/I3's retraction equilibrium point. These results provide a framework for understanding the neural control of feeding in *Aplysia*, and more generally, suggest that biological systems exploit unstable equilibrium points to generate multifunctionality.

Project (or PI) Website

http://www.case.edu/artsci/biol/chiel.htm

Publications

1. Novakovic, V.A., Sutton, G.P., Neustadter, D.M., Beer, R.D. and Chiel, H.J. (in press) Mechanical reconfiguration mediates swallowing and rejection in *Aplysia californica*. Journal of Comparative Physiology – A.

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