# Emergence of Synchrony in Living Materials through Force Interaction

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Abstract:
Biological systems evolve through synchronous co-development of multiple processes. This synchrony is maintained at all scales - cell division to embryogenesis and development. The origin of this precise timing is yet to be fully revealed. Here we show evidence that long range force interaction between biological components might play a role in this synchrony. We discuss two examples. 1) Neuronal junctions: Memory and learning in animals is mediated by neurotransmission at the neuron's synaptic junctions (end point of axons). A large majority of neurons (single neuron cell) have a long (100µm to meters) single axon that forms junctions (synapse) with muscle tissue or another neuron. They carry neurotransmitters enclosed within vesicles that are about 50nm in size. The density of the vesicles is high at the neuro-muscular or neuron-neuron synapse. In response to a stimulus (e.g., mechanical, chemical), the neuron generates an action potential (a voltage wave) that propagates through the axon, arrives at the junction and triggers the release of the neurotransmitters through exocytosis of the vesicles. The more a synapse is used, the higher is the amount of vesicle release in response to the same input stimulus, i.e., higher is the synaptic plasticity. This usage dependent synaptic strength is believed to be the basis for memory and learning. A central dogma in neuroscience is that, clustering is the result of a complex biochemical signaling process. Here we show, using embryonic Drosophila (fruit fly), that during development, an interaction force between the axon and muscle co-evolves with clustering of vesicles at the synapse. If force is released, clustering disappears. If force is supplied, clustering is restored. A hypothesis on the origin of the axonal force and its link to the vesicle clustering will be discussed. 2) Synchronous beating of cardiac tissue: It is generally understood that cardiac cells synchronize their beating through electro-chemical signalling. We show, theoretically and experimentally, that isolated cardiac cells can communicate with each other through force interaction with the intervening deformable media. Such communication leads to coupled dynamics and emergence of synchronous beating. The interaction between the cells depends inversely with the elastic modulus of the media, and the distance between them. This finding may explain asynchronous beating of the atrium in patients with atrial fibrillation where the stiffness of the atrial wall becomes significantly harder due to fibrosis.

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