

LESSONS FOR BIO-INSPIRED DESIGN: FLUID DYNAMICS OF EMBRYONIC HEART

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Nature has shown us that some hearts do not require valves to achieve unidirectional flow. In its earliest stages, the vertebrate heart consists of a primitive tube that drives blood through a simple vascular network nourishing tissues and other developing organ systems. Traditional developmental dogma states that valveless, unidirectional pumping in biological systems occurs by peristalsis. However, our in vivo studies of embryonic Zebrafish heart (Nature 2003) where we mapped the movement of both the myocardial cells in the developing heart tube wall as well as the flow of blood through the tube contradicts the notion of peristalsis as a pumping mechanism in the valveless embryonic heart. Instead, we have discovered an intriguing wave reflection process based on impedance mismatches at the boundaries of the heart tube (Science 2006). From these observations we have developed a physio-mathematical model that proposes an elastic wave resonance mechanism (JFM 2006) of the heart tube as the more likely pumping mechanism. In this model fewer cells are required to actively contract in order to maintain the pumping action than are necessary in a peristaltic mechanism. Inspired by this design, we have succeeded in constructing a series of mechanical counterparts to this biological pump on a range of size scale including scales comparable to that of embryonic zebrafish heart (e.g. ~400 microns). This new generation of biologically-inspired pumps functions on both the micro- and macro-scale and do not possess valves or blades. These advantages offer exciting new potentials for use in applications where delicate transport of blood, drugs or other biological fluids are desired. Also, in this lecture, we will discuss some of our recent experimental observations that may teach us how to grow biological micro-pumps.

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