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Synchrony and neuromechanical sensitivity in the mosquito hearing organ

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Sound detection is a fundamental tool for many biological organisms to sense their environment. Sensing the particle velocity component of sound waves has led to the evolution of exquisitely sensitive auditory organs: small oscillators that are driven resonantly by the sound field. The sound detection threshold is often indistinguishable from Brownian motion. To achieve such low thresholds, the mammalian cochlea incorporates active mechanisms, adding energy to the sound oscillations, and so enhancing sensitivity and selectivity. Mosquito antennae are also endowed with active auditory mechanics. Males use these highly sensitive external antennae to detect the flight sound of females. Sound-induced oscillation of the antenna stimulates thousands of mechanosensory neurones. The antenna exhibits dynamic responses remarkably similar to vertebrate auditory systems: self-oscillation and amplitude-dependent bandwidth both occur. They also exhibit hitherto unseen nonlinear responses including mid-level amplification and hysteresis. The mechanisms for these effects are thought to derive from ciliary motility in the mechanosensory neurones. We show that synchronization in the motile neurones generates large stable coherent forces that provide the antenna with its nonlinear response characteristics. Synchronization ensures a coherent neuronal output, improving signal fidelity. Finally, coherent force modifies the dissipation of antennal energy, changing the bandwidth and enhancing sensitivity.