best-connected nodes¹⁴. The possibility that the web of sexual contacts has a scale-free structure indicates that strategic targeting of safe-sex education campaigns to those individuals with a large number of partners may significantly reduce the propagation of sexually transmitted diseases.

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Biomechanics

Turning the key on *Drosophila* audition

The genetic dissection of *Drosophila* audition is advancing considerably^{1–4}, but complementary studies are needed to unravel the chain of mechanosensory events that bring about hearing in the fly⁵. Here we investigate the delicate biomechanics of the fly's minute antennal hearing organs and show that they look and work like a lock and key. Rotating in response to sound, the antenna's distal segment mechanically activates the auditory receptors — thereby 'unlocking' the mechanism

of *Drosophila* audition.

In *Drosophila melanogaster*, the antennae mediate the detection of conspecific 'love songs'^{5,6}. Anatomically, each antenna is an asymmetric structure consisting of three segments and a feather-like arista³ (Fig. 1a). Laser vibrometric analysis of sound-induced vibrations⁷ reveals that the arista and the club-shaped third segment together constitute a mechanical entity — the sound receiver. Both antennal parts oscillate sympathetically in response to acoustic stimulation, consistently exhibiting a moderately damped resonance at 426 ± 16 Hz (quality factor, $Q = 1.2 \pm 0.1$; 8 flies; Fig. 1b).

Mechanical measurements at different locations (Fig. 1b) show that the entire

arista oscillates as a stiff rod, with its vibration velocity continuously decreasing from tip to base. Remarkably, this oscillation is accompanied by rotation of the third segment. The 180° phase shift between the mechanical responses of opposite edges (Fig. 1b) unambiguously shows that they move in opposite directions and that this segment rotates about its longitudinal axis. This rotation is a direct consequence of the radial orientation of the arista, which breaks mechanical symmetry. Physically, the arista introduces a moment arm, increases the effective surface area, and thus determines the twisting force (torque) exerted by sound.

When stimulated acoustically, the third segment rotates like the bow of a key (Fig. 1c). Moreover, the proximal part of this segment presents a stalk that fits into a pit in the second segment, like a key in its lock. Extending along the rotational axis, this stalk transmits the rotation 'downstream', like a key's stem (Fig. 1a, c). Before connecting to the second segment, the stalk bends, forming a hook. This hook then oscillates like a key's bit (Fig. 1a, c). This vibration will maximally stretch and compress the auditory receptors which, notably, are attached perpendicularly to both sides of the hook.

Unlike other animals, *Drosophila* makes use of sound-induced rotation to channel acoustic energy to its auditory receptor neurons — it has 'rotational ears'. This unconventional mechanism relies on a simple trick: the hook balances the asymmetry introduced by the arista, thereby guaranteeing a receptor activation that compares to that in other insect auditory systems⁸. The third segment of the *Drosophila* antenna is also the primary organ of olfaction and carries hundreds of olfactory sensilla⁹. As hearing relies on rotation, the two sensory modalities can co-exist without compromising their respective functions. Such an evolutionary solution is elegant; flies did not turn their nose into an ear, they turn their nose to hear.

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Figure 1 Anatomy, mechanical response and operational mode of *Drosophila* antennal hearing organs. **a**, Anatomy. Left panel, scanning electron micrograph showing the three antennal segments (numbered) and the arista; right panel, longitudinal section through segments 2 and 3. Scale bars, 100 μ m. **b**, Mechanical response to acoustic random-noise stimulation. The arista and the third segment exhibit identical resonance characteristics and rotate about the longitudinal axis of the latter. Frequency spectra show the magnitude and phase of the vibration velocity (measured by microscanning laser Doppler vibrometry) normalized to the particle velocity in the sound field (measured by a particle-velocity microphone at the antenna's position⁷). A response magnitude of unity indicates equal vibration velocity and particle velocity, and a phase of $+90^\circ$ means that the vibration velocity leads the particle velocity by one-quarter of an oscillation cycle. The acoustic stimulus (mean particle velocity ± 0.04 mm s⁻¹) induced maximal displacements of ± 20 nm and rotation of $\pm 0.003^\circ$. Insets, measurement sites and colour convention (drawing by P. Bryant¹⁰). **c**, Operational mode, showing analogy between antennal mechanics and a rotating key. Yellow arrows, input force; blue arrows, rotation; red arrows, output force.

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