Jing Wang*, Gregory J. Hannon†, David H. Beach‡

**Genetica Inc., 1 Kendall Square, Building 600, Cambridge, Massachusetts 02139, USA*
†Cold Spring Harbor Laboratory, PO Box 100, Cold Spring Harbor, New York 11743, USA
‡Wolfson Institute for Biomedical Research, University College London, Gower Street, London WC1E 6BT, UK
e-mail: d.beach@ucl.ac.uk

1. Harley, C. B., Futcher, A. B. & Greider, C. W. *Nature* **345,** 458–460 (1990).
2. Harley, C. B. *Mutat. Res.* **256,** 271–282 (1991).
3. Bodnar, A. G. *et al. Science* **279,** 349–352 (1998).
4. Wang, J., Xie, L. Y., Allan, S., Beach, D. & Hannon, G. J. *Genes Dev.* **12,** 1769–1774 (1998).
5. Morales, C. P. *et al. Nature Genet.* **21,** 115–118 (1999).
6. Jiang, X. R. *et al. Nature Genet.* **21,** 111–114 (1999).
7. Sun, P., Dong, P., Hannon, G. J. & Beach, D. *Science* **282,** 2270–2272 (1998).
8. Wu, K. J. *et al. Nature Genet.* **21,** 220–224 (1999).
9. Alitalo, K. *et al. Biochim. Biophys. Acta* **907,** 1–32 (1987).
10. Kiyono, T. *et al. Nature* **396,** 84–88 (1998).
11. Foster, S. A. & Galloway, D. A. *Oncogene* **12,** 1773–1779 (1996).
12. Kim, N. W. *et al. Science* **266,** 2011–2015 (1994).

Insect perception

Do cockroaches 'know' about fluid dynamics?

Animals use their senses to extract information from the world around them, so they need to be able to gauge the physical properties of their environment in order to build up an accurate perception of it. For example, a bat needs to 'know' the velocity of sound to estimate how far away an object is, although input to a sensory system may often exploit more complicated properties than this. Here we measure the response by the wind-sensing system of the American cockroach (*Periplaneta americana*) to a complex hydrodynamic flow. We find that the insect's interneurons relay crucial information about the wind's spectral properties, which may warn it of approaching predators.

The cockroach senses minute air movements using tiny hairs on two posterior appendages called cerci[1]. It can surmise the direction of an attack and scurry away to avoid being eaten. Neural signals from the hairs converge on the terminal abdominal ganglion where the wind information is processed, and are then conveyed further by giant interneurons. Although this system has many of the properties of more complex systems, it remains simple enough to be tractable for study.

We produced random wind stimuli with defined spectral properties and measured the average firing rates of several interneurons in response to this stimulus. For a given spectral shape, the total power of the stimulus did not change the steady-state firing rates of the interneurons (Fig. 1a).

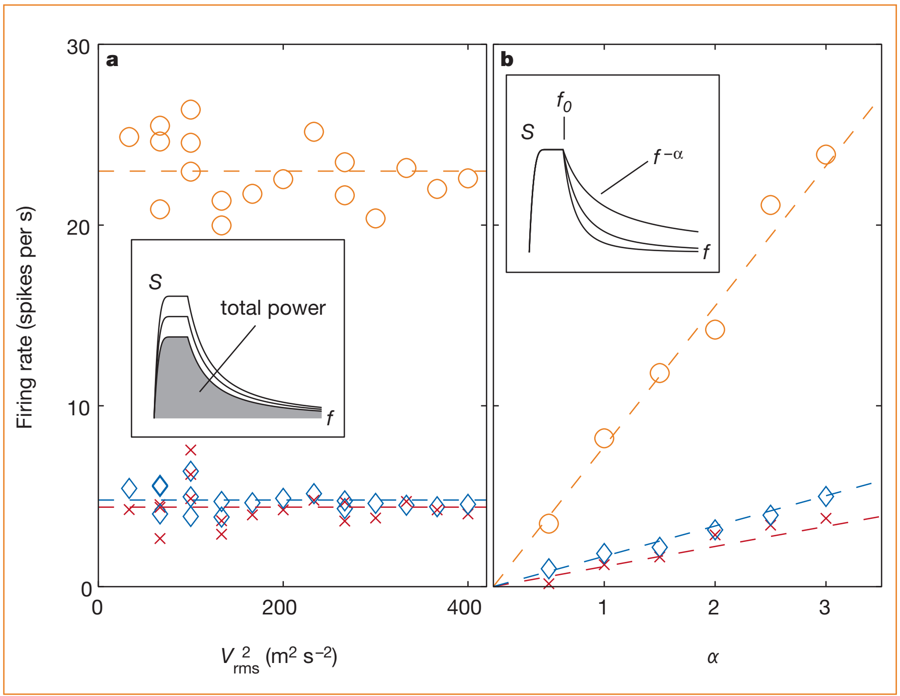

Figure 1 Average firing rate for random wind stimuli with different spectral parameters. Rates are shown for two typical interneurons (red crosses and blue diamonds) and for all interneurons together (orange circles). Inserts show spectral density, *S*, as a function of frequency, *f*, indicating how the spectral parameters were changed. The frequency f_0 was held constant for these experiments at 10 Hz. The total power, which is directly proportional to the r.m.s. of the square of the wind velocity, V_{rms}^2, and the high-frequency 'roll-off' parameter, α, were changed independently. **a,** Firing rate as a function of total power of wind spectra with $\alpha = 3$. **b,** Firing rate as a function of α shows strong dependence on the extent of the high-frequency tail.

Changing the high-frequency roll-off, on the other hand, strongly influenced the firing rates of all of the cells (Fig. 1b). Thus, exposing the system to narrow-band, low-frequency noise produces a strong cell response — that is, a high firing rate — whereas exposure to wide-band stimuli does not. In the limiting case of white noise, the firing rate is almost zero — in spite of the fact that the afferent neurons are known[2] to respond to excitations above 100 Hz. Similar effects are expected for this type of stimulus in other systems[3].

Let us now consider the typical airflow in a cockroach's environment. The Reynolds number gives an indication of the degree of turbulence[4]: given the typical size of surrounding objects (less than about 1 m in size) and the relevant wind velocities (0.1 m s^{-1}), the Reynolds number is $Re \approx 10^3$, so cockroaches live in a world that is often turbulent. Spectra with long, high-frequency tails are characteristic of turbulent airflow[5]. In contrast, the first sign of an approaching predator is slow-moving air, whose spectrum has only low frequencies: in the case of attacking toads and wasps, timescales are typically about 50 ms — corresponding to frequencies below about 20 Hz (refs 6,7). A low-frequency, narrow-bandwidth stimulus may thus be an indicator of a possible attack.

It is evident from Fig. 1 that the average firing rate of the cockroach interneurons conveys information about the spectral properties of the prevailing air movement, which change when a predator approaches. Thus, the insect's awareness of these properties and its ability to detect deviations from the norm — in the form of an excess of low-frequency winds — may help it to survive.

D. Rinberg, H. Davidowitz

NEC Research Institute, 4 Independence Way, Princeton, New Jersey 08540-6634, USA
e-mail: dima@research.nj.nec.com

1. Camhi, J. M. *Neuroethology* (Sinauer, Sunderland, Massachusetts, 1984).
2. Kondoh, Y., Arima, T., Okuma, J. & Hasegawa, Y. *J. Comp. Physiol. A* **169,** 653–662 (1991).
3. Vedenina, V. Y., Rozkova, G. I., Panjutin, A. K., Byzov, A. L. & Kämper, G. *J. Comp. Physiol. A* **183,** 553–561 (1998).
4. Purcell, E. M. *Am. J. Phys.* **45,** 3–11 (1977).
5. Tritton, D. J. *Physical Fluid Dynamics* (Oxford Univ. Press, Oxford, 1998).
6. Plummer, M. R. & Camhi, J. M. *J. Comp. Physiol. A* **142,** 347–357 (1981).
7. Gnatzy, W. & Kämper, G. *J. Comp. Physiol. A* **167,** 551–556 (1990).

Erratum

Focusing hard X-rays with old LPs

B. Cederström, R. N. Cahn, M. Danielsson, M. Lundqvist, D. R. Nygren

Nature **404,** 951 (2000)

An editing error altered the intended meaning of the last two sentences of the seventh paragraph, which should read "We used PVC for focusing. As it contains a large fraction of chlorine, it provides less gain than PMMA, for example." Thus PVC is inferior to PMMA, but we used it for demonstration anyway.