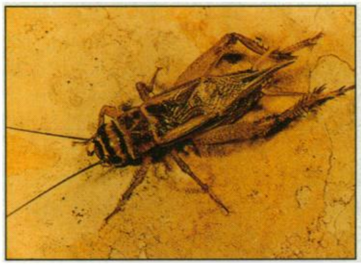
LETTERS

Cricket Research

Research described by Sunny Bains in the article "Even a robot cricket always gets her mate" (Research News, 16 Dec., p. 1809) can lead to a better understanding of the female cricket's sound localization ability and may provide better insight into the functioning of neuron-based auditory systems in general. Biologists have been aware of the cricket's sound localization ability for over half a century, but have not yet found a satisfactory explanation for it. Evidence suggests that the primary function of the cricket's trachea may be to convert amplitude disparities to temporal disparities, so that sound localization information is encoded as a temporal disparity of the axon spikes in the auditory nerves. This explanation would be consistent with the cricket's anatomy and nervous system and is analogous to the performance of an electronic circuit built to solve a similar problem in signal processing.



Playing cricket. Courting and sound judgment.

F. Huber and J. Thorson have summarized (*1*) research on cricket auditory-neuron physiology and behavior. Cricket acoustic anatomy includes two ears located in the forelegs and a complex air-filled tube (trachea) connecting them. Each ear has directional sensitivity, which is believed to be the basis for the cricket's sound localization ability. The ears are connected by auditory nerves containing 55 to 60 axons to the ON/1 omega neurons, which exhibit a (temporal) reciprocal inhibitory response (*2*).

Syllables (sinusoidal tone-bursts) are the basis for communication. Treadmill behavior shows that the cricket meanders toward the sound source (positive phonotaxis) when 5- to 20-millisecond syllables of 5-kilohertz (kHz) tones are grouped in chirps or trills, but not toward continuous tones. When the tone is above 7 kHz, the cricket meanders away from, or at a fixed angle to the sound source (negative or anomalous phonotaxis) (*3*, figure 8). The sound power ranges from about 45 decibels of acoustic power (dBa) to 95 dBa, a dynamic range of 50 decibels (dB), or 300 to 1 in amplitude.

It is estimated that the cricket must measure the ear-to-ear sound amplitude disparity to an accuracy of about 2 dB in order to localize the sound source. Unless the auditory receptor spikes are encoded in a hierarchical system (for example, binary or logarithmic amplitude encoding, and there is no evidence for this), 60 axons are insufficient to encode the amplitude disparity over this dynamic range. If, however, the amplitude disparity is transformed to a temporal disparity (with about 10 microseconds per decibel of amplitude disparity), then simple neural (majority) logic would suffice, provided the ON/1 neurons have a reciprocal inhibition resolution of about 30 microseconds.

A transversal delay line such as the trachea can convert the amplitude disparity to a temporal (or phase) disparity. The amplitude-to-phase conversion ratio can range from 5° to 20° of phase shift per decibel of amplitude disparity, and is independent of the signal power. This same principle is used in electronic systems to measure small amplitude disparities over large dynamic ranges (*4*).

The required timing resolution could be achieved if the first auditory receptor spikes in each syllable, synchronized by the leading edge of the syllable, all arrive at the ON/1 neuron within a 200-microsecond interval (one period of carrier sinusoid). Sixty axons are sufficient to ensure that a statistically significant number of spikes on one auditory nerve arrive at the ON/1 before the first spike arrives on the contralateral side. The reciprocal inhibition physiology of the ON/1 then enables the ipsilateral postsynaptic spiking and inhibits the contralateral side.

If the tracheal phase delay exceeds 180°, the amplitude-to-phase conversion ratio changes sign. In the cricket, this would cause either negative or anomalous phonotaxis above 7 kHz, depending on details of the trachea, and whether the auditory receptor neurons are sensitive to air velocity or pressure.

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References and Notes

1. F. Huber and J. Thorson, *Sci. Am.* **253**, 60 (December 1985).
2. A. L. Selverston, H-L. Kleindienst, F. Huber, *J. Neurosci.* **5**, 1283 (1985).
3. J. Thorson, T. Weber, F. Huber, *J. Comp. Physiol.* **A146**, 361 (1982).
4. R. E. Shafer, *RF Design* **9**, 74 (September 1986). Amplitude disparity to phase disparity conversion is used to localize the proton beams in the Fermilab Tevatron.

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Research in Latin America

I read with great enthusiasm the exciting special issue about science in Latin America (10 Feb., p. 807) and Francisco J. Ayala's Policy Forum (p. 826). As a former director (1990–1993) of the Brazilian research and development (R&D) funding agency CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico), I congratulate the *Science* reporting team for this impressive issue. I have reasons to appreciate the subject matter because most of the time during my term as director of CNPq, it was necessary to fight with its administration and government bureaucracy to maintain a reasonable budget. The problem was, and still is, to obtain an increase in research grants without affecting the fellowships budget. As pointed out there was a "cataclysmic decline" in R&D spending in Brazil, especially in the years 1991–1992, the most critical period of Collor de Mello's presidency.

Despite this irresponsible policy, the output of the Brazilian scientific community experienced incredible growth: publications in the most acknowledged international periodicals increased from 2951 in 1986 to 4267 in 1993, and the impact of these articles also increased substantially. The number of Master's and Ph.D. degrees awarded annually increased from 3931 and 718, respectively, in 1985, to 6841 and 1504 in 1992. Furthermore, science-based technological advances were and continue to be achieved in many fields throughout the country.

Unfortunately, the *Science* special issue did not cover the enormous effort of Brazil in training human resources for science and technology. It also did not report on the possible foundation of a Pan-American R&D funding agency, a welcomed initiative that is under way as a result of AAAS leadership during Francisco Ayala's presidency.

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Ayala's Policy Forum and Daniel E. Koshland Jr.'s editorial on the same topic (10 Feb., p. 771) give only a partial view of the present problems of scientific research in Spanish- and Portuguese-speaking countries of America. As Ayala states, the pace of investment in scientific research in Argentina hastened during the late 1970s and early 1980s, but the actual number of research articles indexed by the Institute for Scientific Information sharply declined in the late 1970s. In 1983, the number of cited articles had not yet returned to the number cited in 1973. That means that the "hastened pace of investment" referred to by Ayala was, in fact, useless and that funds were probably misapplied by the military in power in Argentina from 1976 to 1983. This was the well-known time of the "desaparecidos" (the "disappeared"), when at least 9000 people were killed and tortured in Argentina. Several hundred research scientists were among those who disappeared, and a greater number went into forced exile to save their lives. Today, Argentina has not yet recovered from these events. It is therefore difficult to see how one can conclude that the net result of these two decades is "positive." In fact, Unesco data presented by Ayala are contradicted by