A Mystery of Nature: Mangroves Full of Fireflies Blinking in Unison

By WALTER SULLIVAN
Published: August 13, 1991

MATHEMATICIANS are embroiled in a new round of debate as they try to explain one of the leading mysteries in nature: why do trees full of Southeast Asian fireflies flash in unison?

The unusual insects, beetles of the family Lampyridae, have long fascinated scientists. Experts hope greater understanding of the insects' strange ways will help explain a number of analogous phenomena, including the synchronous firing of cells in the human heart's natural "pacemaker," the brain cells that emit electric signals in rhythm and the cells in the pancreas that control the release of insulin. A recent study of such pancreas cells has shown that they produce coordinated signals only when working in a group of 50 or more.

A number of mathematicians are now arguing that synchrony comes naturally to a variety of oscillating systems. These include not only fireflies but a number of other organisms and body cells that have a preferred rate of natural oscillation. Blinking Causes Debate

The fireflies live on mangroves and other trees found on riverbanks throughout Southeast Asia. The insects gained scientific prominence in 1935, when Hugh M. Smith, a biologist in Washington, described them in the journal Science. His report was greeted with widespread disbelief; some scientists called the blinking an illusion, others called it a fleeting coincidence. But his description has since been confirmed by the careful observations of many scientists.

"Imagine," he wrote, "a tree 35 to 40 feet high thickly covered with small ovate leaves, apparently with a firefly on every leaf, and all the fireflies flashing in perfect unison at the rate of about three times in two seconds." Between flashes the tree was in complete darkness, he said.

"Imagine," he continued, "a tenth of a mile of river front with an unbroken line of Sonnerati trees with fireflies on every leaf flashing in synchronism, the trees at the ends of the line acting in perfect union with those between."

In the early part of this century, it was proposed that the males of the species evolved to blink in unison so that the light would penetrate the dense vegetation along tropical rivers and attract females. Other specialists have been skeptical. The existence of a "maestro" who sets the pace like a band leader seems to be ruled out because each fly can see only about 100 others, they argue.

In a recent issue of The Journal of Applied Mathematics, Dr. Renato Mirollo, a mathematician at Boston College, and Dr. Steven Strogatz, a mathematician at the Massachusetts Institute of Technology, cite a variety of other biological oscillations that become synchronous.

In addition to cells that fire together to control heart beat, the oscillations include crickets that chirp in unison and the menstrual cycles of women living together, as in prisons or dormitories.

Dr. Mirollo and Dr. Strogatz "show that synchrony is the rule for mathematical models in which every firefly interacts with every other," said Dr. Ian Stewart of the Mathematics Institute at the University of Warwick in England, who discussed the work in a recent issue of the journal Nature. He said they had proved to their satisfaction a 1975 conjecture of Dr. C. S. Peskin, professor of mathematics at the Courant Institute of Mathematical Sciences at New York University, that was derived from his attempt to explain why pacemaker cells of the heart function synchronously. He concluded that it was a form of "self-synchronization."

Based on the work of Dr. Mirollo and Dr. Strogatz, Dr. Stewart pointed out, the insects do not have to see all the others, so long as no group is completely out of sight. Insects Pick Up a Rhythm

After the firefly or pacemaking heart cell has fired, according to Dr. Mirollo and Dr. Strogatz, it gradually builds up its potential to fire again, like a toilet tank filling with water. When one nearby cell fires, all the neighboring ones are stimulated to do so, too. Eventually they do not need such a cue. Some adjustable pacemaker enables each insect to fall in with the rhythm of the group. Synchrony spreads through the assembly until all are flashing together.

In a recent article written for The Journal of Mathematical Biology, Dr. Bard Ermentrout, a mathematician at the University of Pittsburgh, said he believed that the insects could be stimulated to flash in unison at rates that are above or below their preferred rate, within limits. One question has been how radically they could alter their natural pulse rate to accommodate unfamiliar flash rates.

He points out that the innate pacemaker in the species native to Thailand, Pteroptyx malaccae, can adjust to tempos as much as 15 percent above or below its natural rhythm. Researchers compare the phenomenon to the manner in which an enthusiastic audience quickly synchronizes its hand-clapping. Dr. Ermentrout says that, unlike fireflies, there are no strict limits to the rate of such clapping. But an audience tends to fall into a rhythm that it finds comfortable.

The various species of synchronizing firefly are scattered from India to Southeast Asia, Malaysia, New Guinea and the Philippines. Some researchers believe no single pace-setting process applies to them all.

One goal of firefly research, according to specialists in the field, is to examine what interrupts their synchrony and how it is restored.

In the 1970's Dr. John Buck, then director of the Laboratory of Physical Biology at the National Institutes of Health, and his wife, Elisabeth, conducted pioneering studies of the insects in Thailand. At dusk, they said, each firefly "receives many conflicting pulses during the incoherent initial stage" gradually becoming synchronous. The insects apparently remain in the same tree for a considerable time and Malayan rivermen count on them at night as aids to navigation.

The Bucks found that the insects, when exposed to artificial flashes at a rate similar to that characteristic of their species, synchronize within one or two cycles and reset their pacemaker to remain precisely in synchrony. If the artificial flashes are substantially different from the insect's natural rate, the insects will not be quite in phase, acting on cue rather than on their own pacemaker. A Lab in a Hotel Room

The Bucks captured bags of fireflies, took them to a Bangkok hotel, sorted out the males and released 50 of them at a time in their darkened room. "At first the insects flew about, flickering rapidly and sometimes darting at each other like moths at a candle," they wrote. Gradually the insects settled on the walls in small groups, flashing at their characteristic pulse rate, but independently. Finally the insects within each group began to synchronize.

They told of a test in which a researcher studying another species near Singapore flashed a string of lights at the natural rate of that species. Clouds of male fireflies flew out of their trees toward the lure "as if they were being drawn by a giant vacuum cleaner," they reported.

Drawing