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STRANGE, SCROLL-LIKE WAVE IS LINKED TO BIOLOGICAL PROCESSES

By WALTER SULLIVAN

A STRANGE class of waves that unrolls as paper does from a scroll appears to have a key function in many biological processes, from heart attacks to the behavior of social amoebas and attacks of epilepsy, according to a recent analysis by researchers at Purdue University. Some physicists suspect that they may also control the behavior of subatomic particles.

Because the scroll waves produce chemical or electrical transformations, rather than any physical motions, they are difficult to visualize. Nevertheless, since they can be represented mathematically, it has been possible to display them graphically through manipulations by a Cray-1 computer, one of the world's most powerful, at Los Alamos National Laboratory in New Mexico.

Displays of the outward-spiraling waves resemble the internal structure of spiral sea shells, and Dr. Arthur T. Winfree of Purdue University, who has specialized in such phenomena, said last week that his office was full of sea shells sectioned in various ways with a glass cutter.

Similar Class of Waves

The waves are related and may behave in ways similar to a class of waves, known as solitons, recently recognized as having widespread effects in the atmosphere, in bodies of water and on a subatomic scale. Solitons occur singly, rather than in a procession of waves.

When solitons meet they can pass through one another without alteration, whereas that is not true of scroll waves. Some solitons, such as the internal waves recently observed in certain ocean regions, do involve physical movement. They move along a boundary between water masses of differing density, rather than along the surface.

A two-dimensional display of scroll waves, seen in cross section, occurs in a thin film of mixed chemicals known, for its Soviet discoverers, as the Belousov-Zabotinsky reagent. Its properties, first recognized in the 1950’s, were so strange that they were not reported in print until further investigated in the 1960’s.

According to Dr. Winfree, a professor of biology at Purdue, the mixture is normally the color of tea. But, he said in a telephone interview last week, if it is stimulated, as with a hot pin or a beam of
ultraviolet light, the affected spot turns electric blue.

The blue region - a zone of transient chemical excitation - spirals outward like the spray of water from a rotating lawn sprinkler. Behind its advance the mixture returns to its tea color. In a thicker layer of the mixture the spiral begins to look like an unwinding scroll.

It has been through computer-generated graphics, however, that the intricate structure of such waves has been displayed, including situations where the scrolls form rings, are twisted, knotted or joined to other scrolls.

Theory About Heart Problem

Dr. Winfree views scroll waves as possible causes of fibrillation in heart attacks, epileptic seizures and other effects. In fibrillation, the natural pacemaker that electrically controls the complex sequence of muscle responses in each heartbeat fails, and the heart flutters uselessly. When held in the hand, according to his surgical colleagues at Purdue, such a heart "feels like a wad of writhing worms."

Fibrillation, Dr. Winfree pointed out, can strike a normal heart with no evidence of disease. He believes microscopic scroll waves originate at a multitude of points within the heart's electrical control system, overwhelming the pacemaking process.

What initiates such an effect remains uncertain. Last year, in an article on cardiac sudden death in Scientific American, Dr. Winfree described the fatal efforts of George Ralph Mines of McGill University in Montreal to find the cause.

Dr. Mines suspected, from animal tests, that fibrillation could be initiated by an electric impulse of a critical magnitude at a vulnerable moment in the heart's pulse cycle. On Nov. 7, 1914, he tested his hypothesis on himself and later in the day, Dr. Winfree wrote, was found "lying under the laboratory bench surrounded by twisted electrical equipment." He never recovered.

The heart, according to Dr. Winfree, "is continually bombarded by electrical impulses from many sources." Normally, if the pacemaker is electrically disrupted, the heart skips or delays a beat but immediately recovers. It is when the impulse occurs at a vulnerable moment in the electrical cycle, he believes, that multiple scroll waves overcome the heart's control system.

Possible Link to Epilepsy

On the other hand, he suspects that an epileptic seizure begins when a single scroll wave propagates through the brain, causing massive loss of nerve cell potassium and an avalanche of nerve impulses.

Such waves also seem to spread through a colony of social amoebas in a chain reaction that releases cyclic adenosine monophosphate, a key substance in cell chemistry. Each amoeba synthesizes the substance until stimulated to discharge it by its release from a neighboring amoeba.

Mathematical analysis of scroll waves and their three-dimensional display was reported by Dr. Winfree
and Steven H. Strogatz, a graduate student now at Harvard, in the journal Nature. They have further described the simulations with Melvin L. Prueitt of Los Alamos in the journal IEEE Computer Graphics and Applications.

The simulations have helped define the extent to which the scrolls can be twisted, knotted or linked. The resulting pattern of allowed or forbidden configurations, according to Dr. Winfree and Mr. Strogatz, indicates the existence of an "exclusion principle" reminiscent of that affecting the behavior of subatomic particles.

There appears to be a "striking relationship" between the mathematics of scroll waves and that affecting the behavior of quarks and other such particles, Dr. Winfree said recently.