Identifying Chaos in Heart Quakes

Every year, more than 350,000 people in the United States die suddenly of heart attacks, most caused by an abrupt shift from rhythmic pumping to spasmodic convulsions of the heart.

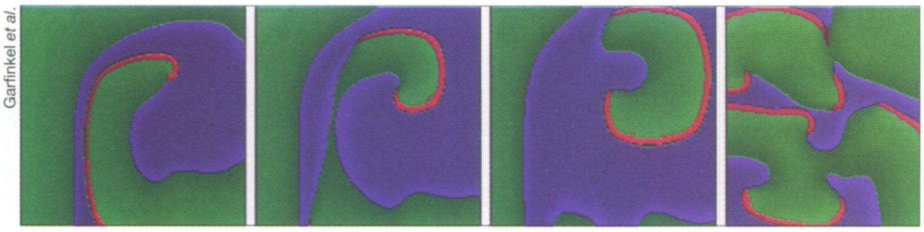
Now, researchers report evidence suggesting that an ailing heart's erratic shivering, known as cardiac fibrillation, is a form of chaos. In other words, the irregular beating is not completely random but results from a specific type of deterioration in the organization of the heart's electric activity.

Alan Garfinkel, a cardiology professor at the University of California, Los Angeles, and his colleagues describe their findings in the Jan. 15 JOURNAL OF CLINICAL INVESTIGATION.

The observations represent the "best evidence to date implicating chaotic behavior in fibrillation in human and canine hearts," says Richard L. Verrier of the Beth Israel Deaconess Medical Center in Boston.

The discovery of a specific pathway to chaos in cardiac fibrillation also opens up the possibility of new therapeutic strategies that may help prevent fibrillation, Garfinkel suggests.

Normally, with each successive heartbeat, an electric wave front propagates across the interconnected muscle fibers of the heart, causing them to contract.


Garfinkel et al.

In this computer simulation of the onset of cardiac fibrillation, a spiral wave of electric activity (left), which circulates in a sheet of heart tissue, deteriorates into a chaotic stage (right), in which several meandering spiral waves cause irregular contractions. Red indicates cells in which the voltage is rising, green where it is falling, and blue where it is zero.

However, such a wave can occasionally get stuck—perhaps because of some abnormality in the tissue—and begin rotating as a spiral wave (SN: 9/5/92, p. 156). Scientists have predicted that this rotating disturbance can break free and begin to circulate as a unit in the heart tissue. It may also break up into a small number of additional spiral waves, all rotating and meandering at different rates.

Garfinkel and his group looked for evidence of this pattern of behavior in cardiac recordings of five patients who suffer from chronic atrial fibrillation, in multi-electrode recordings of electric activity during ventricular fibrillation in the excised, intact heart of a dog, and in maps of electric activity across thin slices of human and canine cardiac tissue in the lab.

Their measurements showed waves of electric activity consistent with a scenario in which a meandering spiral wave breaks up into additional spiral waves, causing the system to destabilize and become chaotic.

"The data suggest that fibrillation is a form of . . . chaos," Garfinkel says. "Characteristic oscillations precede and precipitate fibrillation."

The chaotic behavior appears to arise because of interactions among distinct spiral waves meandering at different rates. A computer simulation of the process in a sheet of cardiac tissue supports the findings. The effect resembles the way in which a smoothly flowing liquid breaks up into vortices, becoming turbulent.

"They've made a very strong case that, at least in some situations, the transition to fibrillation involves spiral waves," says physicist William L. Ditto of the Georgia Institute of Technology in Atlanta, who studies cardiac excitations.

"There's a lot of interest in understanding the stability of spiral waves in the heart," notes physiologist Leon M. Glass of McGill University in Montreal. Identifying the instabilities involved in fibrillation is difficult both theoretically and experimentally. "It's important to try to document them," he says.

Garfinkel and his colleagues attribute spiral wave instabilities to a characteristic known as restitution, which governs how quickly a heart cell recovers from one beat to the next. Changes in the recovery rate of a subset of cells can trigger spiral wave meandering, the researchers say.

The UCLA study offers clues as to what kinds of electrocardiogram signals might serve as predictors of cardiac fibrillation, Verrier remarks. "The chances are quite reasonable that this kind of an approach will work."

"With these kinds of studies," Ditto adds, "we have a real chance to make a major breakthrough." — *I. Peterson*

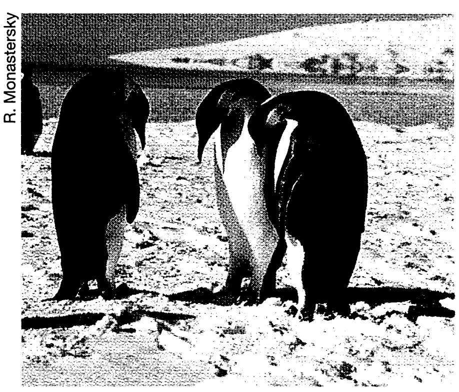
Space jam: Energetics of a penguin huddle

For Antarctica's Emperor penguins, now is the season of sun and plenty. By March, male birds will begin a fast that lasts 105 to 115 days, during which they will incubate a single egg through the dark polar winter. They'll live off the fat stores they are now laying down, but they will depend on their fellow fathers-to-be for survival.

Thousands of males jam together, eggs balanced on their feet and backs to the wind, in heat-conserving huddles. Not a lot goes on. The penguins "are somewhat torpid, like hibernating bears," says Yvon Le Maho of the Centre National de la Recherche Scientifique in Strasbourg, France.

In the first look at the energetics of Emperor penguins in the wild, Le Maho and her colleagues have gauged just how efficient the huddle is. They compared the metabolic rates of 8 penguins that wintered in a crowd of 3,000 birds and 10 penguins kept in pens outdoors. By measuring change in body weight and water use before and after incubation, the researchers calculated that the huddling penguins burned fat stores at a 17 percent lower rate than captive penguins did. The huddling birds finished with 7 percent more body mass than the captives.

Without huddling, the researchers report in the Jan. 23 NATURE, Emperor penguins would run out of energy 3 weeks early and have to abandon their eggs. — *C. Mlot*


R. Monastersky

Before the winter huddle, Emperor penguins can weigh 80 pounds.