Seeing and controlling chaos in the brain

Just as the increasing sophistication of microscopy techniques have enabled neurobiologists to view nerve cells as they never could before, tools borrowed from mathematicians and physicists are now providing new insights into the electrical activity of these cells.

Predictable patterns *do* exist amidst the din of electrical impulses used by nerve cells to communicate with one another, says Steven J. Schiff of Children's National Medical Center in Washington, D.C. Until now, discerning such patterns has proved elusive. Although nerve cells sometimes fire regularly, they often change their timing unpredictably.

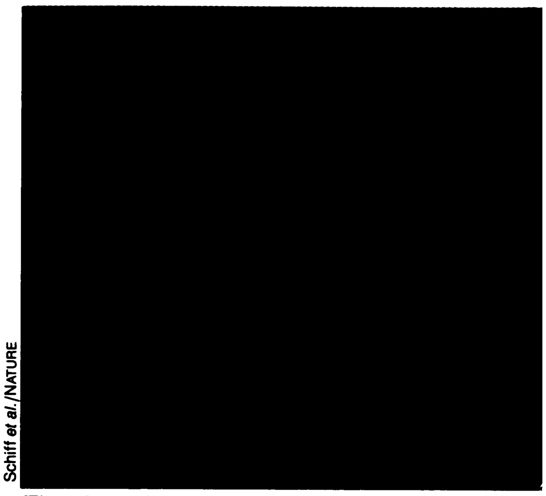
Actually, at least in an experimental setup, the patterns can be chaotic: They do have some predictability even though they look irregular, explains William L. Ditto, a physicist at the Georgia Institute of Technology in Atlanta. By anticipating the resulting patterns in the tested tissue and controlling the degree of irregularity, he and Schiff think they may one day successfully stifle the impulses that lead to epileptic seizures.

Working with Mark L. Spano at the Naval Surface Warfare Center in Silver Spring, Md., these researchers demonstrated this chaotic behavior — and control of that behavior — in thin slices of a part of the rat brain called the hippocampus. Bathed in a concentrated potassium solution, some cells in these slices synchronize their firing as "bursts." Parts of the slice then become epileptic.

With electrodes attached to the slice, the team tracked the timing between each impulse, or spike, and of changes in this timing and found nonlinear procedures for describing what they saw, they reported in the Aug. 25 NATURE.

Once they determined the chaotic, albeit tractable, nature of the spiking patterns, they began fiddling with it. By electrically jolting the slice briefly at calculated moments, they tried to alter the firing of cells, Ditto says.

After 91 tests of 22 slices from 9 rats, they were convinced: "We can make [the slice pattern] chaotic; we can make it periodic; we can make it do almost anything," Ditto says. Seizures develop because too many nerve cells start to fire at once in too regular a fashion. Ditto suspects the so-called "anti-control" whereby they make the pattern more chaotic may help prevent seizures.



Schiff et al./NATURE

This chart shows how dispersed chaotic pulses can be made more erratic (anti-control), less erratic with single control pulses, and practically synchronized with double control pulses.

While an impressive demonstration of chaos and of the application of chaos controls to a complex biological system, the experiment still does not prove such chaos really exists in an intact brain, cautions Walter J. Freeman, a neuroscientist at the University of California, Berkeley. "The questions of whether [these dynamics] occur physiologically as part of normal brain function or are induced — these are all issues being hotly debated," he says.

Still, Schiff is unfazed. Before he surgically removes a part of a human brain that instigates seizures, he first monitors the electrical patterns to determine where these aberrant signals originate. The patterns he observes are more variable, but they still parallel measurements taken from the slices, he notes. Thus, he thinks studies in these slices will provide valuable information about human brains.

Also, chaos control looks promising in other organs. Two years ago, Spano and Ditto worked with cardiologists and demonstrated that hearts, too, exhibited chaotic behavior that the researchers could control (SN: 9/5/92, p.156). That data compares well with heartbeat data collected from people.

Schiff hopes a similar approach will help some epileptics avoid surgery to remove parts of their brain because drugs could not control their seizures. The idea of using electric fields and currents to alter brain activity is not new, but the use of chaos control procedures offers a chance for "more subtle intervention and more accurate control," Schiff says. — *E. Pennisi*

Using bacteria to get sulfur out of oil

That infamous bad-egg fetid scent is sulfur's hallmark. It is also a major problem for petroleum refiners, who by law must drive their fossil fuels through lengthy and costly catalytic steps to expunge sulfur from their best oil and gasoline blends.

Burning sulfurous fossil fuels causes air and water pollution, including damage to the environment from sulfur oxide-laden acid rain.

To rid petroleum products of noxious sulfur, most refineries use a method called hydrodesulfurization. At high temperatures and pressures, this technique forces petroleum compounds together with hydrogen gas and metal catalysts, yielding a disposable sulfur by-product.

Yet this method has a problem: It does a poor job of breaking down heavy sulfur compounds that can damage a fuel by lowering its octane level.

Attacking this removal problem from another angle, Steven W. Johnson, a chemical engineer at Energy Biosystems Corp. in The Woodlands, Texas, describes a new method using bacteria to remove sulfur from petroleum products. At the American Chemical Society meeting in Washington, D.C., this week, he explained that the bacterium *Rhodococcus erythropolis* has proved both effective and efficient at removing sulfur from hydrocarbon mixtures without harming the fuel itself.

"Microbes are great catalysts because their actions are very specific," says Johnson. "The beauty of this organism is that it directly attacks the bonds between sulfur atoms and hydrocarbons, snipping the sulfur out without damaging the fuel molecule. It replaces sulfur with a benign oxygen atom, which yields nonpolluting carbon dioxide and water when the fuel is burned.

"The organism uses three enzymes to take dibenzothiophene through a series of oxidation steps, converting sulfur to an inorganic form," Johnson adds. "It's an enzymatic, catalytic process, though the organism doesn't secrete any enzymes. Instead, the enzymes remain intact within each microbe, which acts as a carrier of the catalyst. To drive the reaction, the organism consumes a small portion of the fuel for energy."

Scientists at the Institute of Gas Technology in Des Plaines, Ill., originally identified the bacterium, called IGTS8, in 1989. Since then, research teams have studied its catalytic capacities — primarily its tendency to convert dibenzothiophene into a hydrocarbon without sulfur and a benign sulfur compound. The sulfate residue, says Johnson, can be readily made into ammonium sulfate, a widely used fertilizer.

A pilot plant demonstrating this new bio-desulfurization system will begin operating in early 1995 at Energy Biosystems, Johnson says. Initially, the plant will produce only one to five barrels of desulfurized oil a day. Ultimately, the goal is to scale up from what Johnson calls "a shake-flask process to 40,000 barrels a day." — *R. Lipkin*