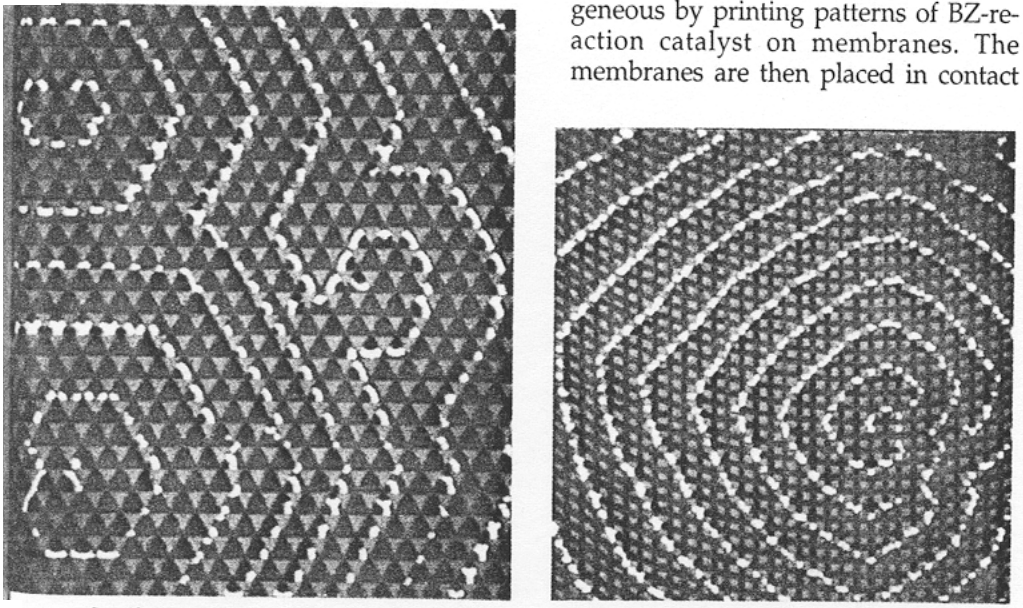
Chemical wave method models biological systems

With an experimental setup that's just a tad out of the ordinary—an ink-jet printer that shoots catalyst molecules onto membranes in patterns set up with a commercial software program—researchers are using chemical systems to model wave phenomena that occur in the beating heart and other biological systems.

West Virginia University (Morgantown) chemistry professor Kenneth Showalter, visiting assistant professor Oliver Steinbock (from the Max Planck Institute for Molecular Physiology, Dortmund, Germany), and graduate student Petteri Kettunen use the unusual experimental approach to produce chemical wave behavior in inhomogeneous (spatially nonuniform) media [*Science,* **269,** 1857 (1995)].

The chemical system is based on the Belousov-Zhabotinsky (BZ) reaction, the cerium-ion-catalyzed oxidation of malonic acid by acidified bromate. The BZ reaction is an oscillatory reaction that produces chemical waves and other types of dynamic patterns as well as chaotic phenomena.

BZ systems are typically homogeneous. But Showalter, Steinbock, and Kettunen make them spatially inhomogeneous by printing patterns of BZ-reaction catalyst on membranes. The membranes are then placed in contact with thin layers of BZ solution lacking catalyst.



Catalyst patterns (dark gray) on membranes in contact with Belousov-Zhabotinsky solution (without catalyst) can cause formation of chemical waves (white) in various shapes, including hexagons (left) and diamonds.

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When the reaction is run under these conditions, says Showalter, "The main thing you find is that the local pattern affects the global wave geometry. So if you have a local pattern of a checkerboard on a very fine scale, then globally you'll get a diamond-shaped wave instead of your normal circular wave."

In addition, spiral wave sources appear spontaneously in the experimental system and serve as organizing centers for surrounding wave activity. In the past 20 years, studies by biology professor Arthur T. Winfree of the University of Arizona, Tucson, and others have provided important insights on the role played by spiral waves in heart maladies such as tachycardia and fibrillation.

Most experimental studies of chemical excitable media have focused on homogeneous systems, even though biological media are spatially inhomogeneous. The work by Showalter and coworkers provides an opportunity to extend chemical wave studies to excitable media in which inhomogeneities can be designed systematically.

Asked to comment on the work, professor of theoretical biology John J. Tyson of Virginia Polytechnic Institute & State University (Blacksburg) says: "There are lots of interesting biological systems that show the same sort of wave propagation behavior that Showalter and coworkers are studying. The heart muscle is probably the most important example, but chemical waves also occur during aggregation of the slime mold *Dictyostelium,* in frog eggs, and in neural tissue."

The new technique "provides a better chemical model for the biological systems—one that's better understood from a mechanistic point of view but shows the same sort of qualitative behavior," says Tyson. "The limitation is it's only two-dimensional, and some of the most important things we're looking at nowadays involve wave propagation in three-dimensional systems."

However, Tyson adds, "Showalter and his friends have shown how to create any kind of spatial inhomogeneity that you want by using these ink-jet printers. I think that's a very considerable advance in making the chemical reaction system more like the biological systems that it's trying to mimic."

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