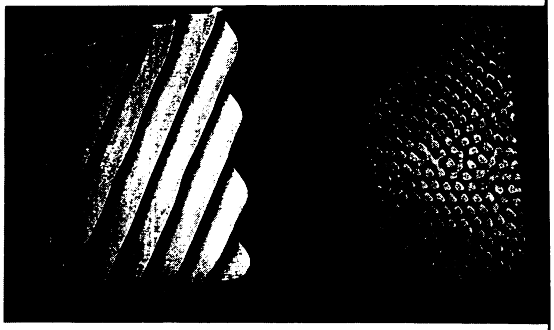
# Generating chemical spots and stripes

The distinctive patterns on the coats of such mammals as leopards, zebras and giraffes have inspired both folk tales and scientific investigations. Now laboratory experiments, supported by theoretical studies, have provided the first steps toward the possibility of linking a single pattern-forming mechanism — originally proposed 40 years ago — with biological patterns.



Swinney & Ouyang

*These computer-enhanced photos show examples of two-dimensional, stationary patterns formed in a gel. Peaks in these images (lighter areas) correspond to low iodide concentrations, whereas valleys (darker areas) correspond to high concentrations. In the gel, these regions show up as yellow and blue patches.*

In 1952, mathematician Alan M. Turing suggested that biological forms mirror patterns in the concentrations of hypothetical chemicals called morphogens. He postulated that, under appropriate conditions, the reaction of these chemicals and the subsequent diffusion of their reaction products combine to create distinctive patterns from an initially uniform distribution of morphogens. He encapsulated this mechanism in a simple mathematical formula.

Experimental evidence that such a mechanism could govern a chemical system didn't emerge until 1990, when Patrick De Kepper and his co-workers at the University of Bordeaux in France produced a stationary pattern of spots in a thin gel continuously fed a fresh solution — containing malonic acid and chlorite and iodide ions — in a special chemical reactor (SN: 8/11/90, p.88).

"The crucial step, in my view, was the development of a reactor with which one could look for sustained patterns," says physicist Harry L. Swinney of the University of Texas at Austin, who led the effort to develop the apparatus both teams used for viewing Turing patterns. "People hadn't appreciated that if you wanted to look for [transitions from uniform states to stationary patterns], you had to maintain the system far from equilibrium."

Swinney and colleague Qi Ouyang then used this apparatus to demonstrate how adjusting the temperature or concentration of one or more of the reacting chemicals could abruptly produce a distinctive, stationary pattern of concentrations — made visible by a chemical indicator, which changes color in the presence of certain substances. In some cases, they could alternately raise and lower the temperature to create, then erase, the pattern.

In such experiments, described by Ouyang at last month's American Physical Society meeting in Washington, D.C., the researchers could start with a system showing no spatial concentration variations and, by adjusting the concentration of one component, produce distinctive patterns of spots or stripes.

Moreover, "if you keep going from the stationary patterns, you eventually get spatially chaotic patterns — states of chemical turbulence," Swinney says.

"These chemical systems are the first clear evidence that the Turing mechanism does actually occur in nature," says chemist Irving R. Epstein of Brandeis University in Waltham, Mass.

Now researchers are trying to find other combinations of chemicals that display Turing patterns. In the May 1 Proceedings of the National Academy of Sciences, Epstein and colleague István Lengyel propose a systematic approach for finding such examples.

They suggest that Turing patterns could arise in combinations of chemicals that under somewhat different conditions produce the swirling, spiral patterns or waves seen in oscillating chemical reactions. To get stationary rather than moving patterns would involve confining the reactions to a gel and ensuring that reaction-inhibiting molecules diffuse more rapidly through the gel than the initial reactants, or "activator" molecules. For example, chemically tying activator molecules to much larger, slow-moving molecules could produce the necessary effect.

"A key question for biologists and biochemists is whether they can find a biological system where they can identify the activator and the inhibitor [molecules] and really show that the Turing mechanism is active in the system," Epstein says.

Swinney notes: "To make a connection between the chemical patterns, which at this point are demonstrably Turing patterns, and actual biological patterns is an important leap that has yet to be made." *— I. Peterson*

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# Ice crystal growth: An electric finding

Sometimes even the simplest materials can baffle scientists. Take ice, for example. Researchers still know very little about how this seemingly mundane substance forms.

Studies conducted over the past four decades have shown that ice crystals sometimes grow around molecular "seeds," substances that give ice a geometric template to mimic and build upon. Scientists first suggested this idea in 1947 after observing that smoke containing silver iodide, a chemical with an ice-like crystal structure, caused ice formation in clouds. Since then, researchers have shown that other substances also seem to act as templates.

Now, Leslie Leiserowitz and his co-workers at the Weizmann Institute of Science in Rehovot, Israel, describe another growth mechanism. They report in the May 8 Science that an electric field appears to cause ice crystals to form.

In their experiment, the group paired various combinations of amino acid crystals. Some combinations resulted in polar, or electrically charged, crystals; others remained electrically neutral. The researchers placed water vapor in the microscopic crack of both kinds of crystals and cooled them. They found that tiny ice crystals started to form at temperatures 4° to 5°C higher in the polar crystals than in the nonpolar crystals. Since amino acid crystals bear no structural resemblance to ice, the team attributes the ice growth to the electric field.

Scientists have suspected since 1879 that an electric field might trigger ice formation, but until now the theory had never been well tested, notes Yale University chemist J. Michael McBride. "This is the kind of experiment you like to see — where you have as many things controlled as possible," he says.

"It is refreshing that careful observation of simple materials can still yield original insight," McBride writes in a review article accompanying the research report. Nonetheless, more experiments are needed to confirm the electric-field theory, he says. "The evidence they've provided is very suggestive, but I don't think they've nailed it down yet."

Exactly how electricity might promote ice growth remains a matter of speculation. One explanation, says McBride, may hinge on ice's structural flexibility, which allows its crystals to form in many molecular arrangements.

Learning more about how ice forms may help investigators discover new ways of stunting its growth. This would have many applications, says Leiserowitz, from preventing icing of airplane wings to keeping cells of frozen donor organs from bursting. *— M. Stroh*

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