Angelfish stripes: A possible explanation

That stripes appear so frequently on the skins of animals bears testimony to their importance. Zebras, skunks, and raccoons, for example, evolved various kinds of stripes, highlighting each species' distinctive environmental needs.

Those on the angelfish *Pomacanthus semicirculatus* offer a particularly striking example of patterning because they maintain a constant width and spacing as the fish grows. To achieve this, the angelfish must introduce additional stripes onto its body rather than stretch out the three it started out with as a juvenile.

Shigeru Kondo and Rihito Asai, molecular biologists at Kyoto University in Japan, now offer a possible explanation for the mechanism underlying this peculiar coloring system: a chemical wave of interacting pigments.

"The stripes of *Pomacanthus* maintain the spaces between the lines by the continuous rearrangement of the patterns," Kondo and Asai note in the Aug. 31 NATURE. The scientists simulated this continuous rearrangement with an algorithm—a mathematical recipe—for a "reaction-diffusion wave." This chemical system starts out with one homogeneous color, then reacts with itself to produce a pattern of alternating colors. First proposed in 1952 by the British mathematician Alan Turing, this model can account for periodic patterns in nonliving systems (SN: 5/9/92, p. 311).

Kondo and Asai believe that this model also explains how an angelfish's striped patterns transform as it grows. Although experimental evidence has never linked this system to an organism, the researchers contend that, when it comes to an angelfish, "a simulation program based on a Turing system can correctly predict future stripe patterns."

In fact, they say, "the striking similarity between the actual and simulated pattern rearrangement strongly suggests that a reaction-diffusion wave is a viable mechanism for the stripe pattern."

The algorithm simulates the behavior of two molecules: an "activator" and an "inhibitor," each of which affects the other's rate of synthesis as the fish grows. As the mock molecules interact, moving through 50,000 runs of the computer program, a pattern emerges that resembles what's observed on an angelfish after 90 days of growth.


National Aquarium, Washington, D.C.

The angelfish Pomacanthus semicirculatus.

"Various models have been put forward to explain stripe patterning," says Hans Meinhardt, a molecular biologist at Germany's Max Planck Institute for Evolutionary Biology in Tübingen. But these have been "undermined" by the finding that the pigment reactions directed by the animals' genes follow different rules from those that the computer obeyed, he notes in a commentary accompanying the NATURE paper.

Nevertheless, he credits Kondo and Asai with demonstrating that a relatively simple chemical mechanism might in fact govern the behavior of the pigments that give rise to the tropical fish's stripes. Indeed, that the stripes of both the angelfish and the new computer simulation branch out in a similar way should prompt more study of the pattern's underlying rules, he told SCIENCE NEWS.

Some of the regulatory features of stripe formation in fishes do parallel those observed in fruit fly embryos, Meinhardt says. Yet this proposed pattern-forming reaction in angelfish differs markedly from the action of the stripe-regulating genes known to exist in the fruit fly.

While he says that this model offers a "fresh look" at stripe formation in growing organisms, Meinhardt concludes that the stripes of the *Pomacanthus* "still call for more explanation."

Kondo and Asai point out that while they do not know which molecules spawn the angelfish's arrangement of stripes, their simulated molecules do mimic the behavior of proteins in water.

Viewing the angelfish's stripes from another perspective, they argue that study of the pigments in the animal's skin may produce a deeper understanding of the chemicals and mechanisms governing pattern formation. In fact, by combining data from fish with those from their simulation, the scientists believe "it should be possible to identify the molecules involved." *— R. Lipkin*

Ocean life in the ice age: Time to party

Given a choice between an ice age climate and today's balmy conditions, most residents of North America and Europe would opt for the warmer weather. But a fish or a whale might pick differently. Emerging evidence suggests that oceanic life enjoyed an extended bash during the last ice age, complete with plenty of nutritious refreshments and unbridled procreation, at least on a microscopic level.

In the Aug. 31 NATURE, Raja S. Ganeshram of the University of British Columbia in Vancouver and his colleagues report that the ice age ocean of around 20,000 years ago appeared to hold higher concentrations of nitrate, a key nutrient for the single celled planktonic plants that anchor the marine food chain. The availability of the extra nitrate during the glacial epoch may have stimulated the proliferation of this basic marine staple in waters now considered nutrient deprived.

Ganeshram's team studied nitrate levels by measuring the concentrations of two nitrogen isotopes—N-15 and N-14—in sediments collected off the coast of Mazatlán, Mexico. This area is one of three principal "nitrate sinks" in the modern ocean—places where bacteria, in a process called denitrification, convert nitrate into a form unusable by most organisms. Because the bacteria more readily consume nitrate containing the lighter nitrogen isotope, researchers can gauge the extent of past denitrification by analyzing the ratio of N-15 to N-14 in the sediments.

Off Mexico, sediments formed during the ice age showed evidence of lower rates of denitrification, suggesting that oceans at that time contained more nitrates for organisms to feed on, the scientists found. Researchers from the Woods Hole (Mass.) Oceanographic Institution, reporting in the Feb. 9 NATURE, had previously obtained evidence of a similar ice age drop in denitrification rates in the Arabian Sea, another principal nitrate sink in today's ocean.

"This tells you something was different in a major way because denitrification was not occurring in areas where it is now," notes J.R. Toggweiler of the National Oceanic and Atmospheric Administration in Princeton, N.J. But he cautions that scientists lack even basic data about the source of nitrate in today's ocean. Without more information, they cannot definitively deduce the global nitrate content of the ice-age oceans from the measured denitrification rates at just two sites.

Higher nutrient concentrations during the ice age could help explain a persistent puzzle about the glacial world, according to Ganeshram and his coworkers. From studies of ice layers in Antarctica and Greenland, researchers know that atmospheric carbon dioxide concentrations dropped during the glacial period, weakening Earth's natural greenhouse effect. If a surfeit of nutrients fertilized marine plankton during the ice age, the plants would have sopped up carbon dioxide as they grew, thereby reducing atmospheric concentrations of this gas.

— R. Monastersky