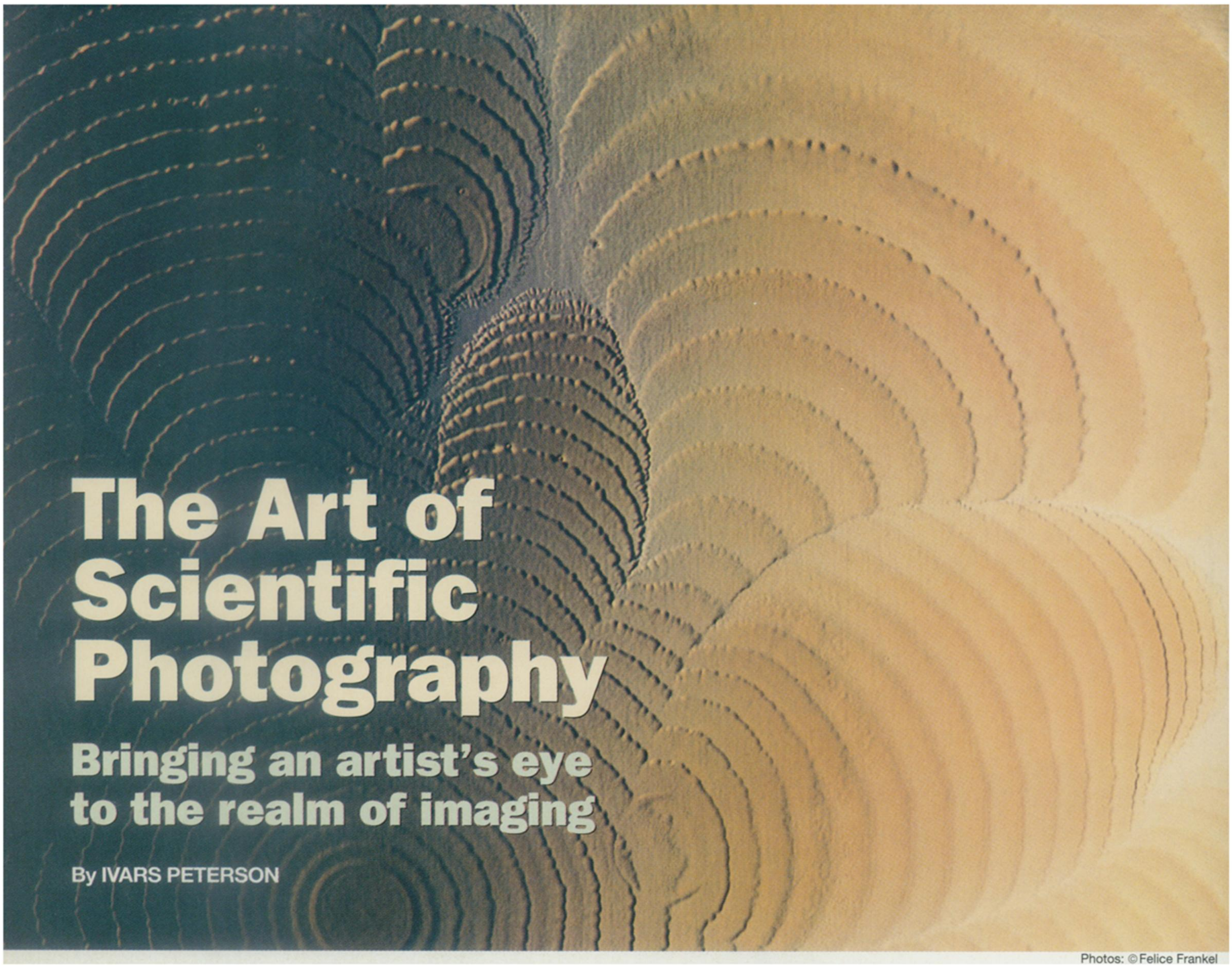


The Art of Scientific Photography

Bringing an artist's eye to the realm of imaging

By IVARS PETERSON

Photos: ©Felice Frankel

"Look at me!" the images exclaim. "Pay close attention," they insist.

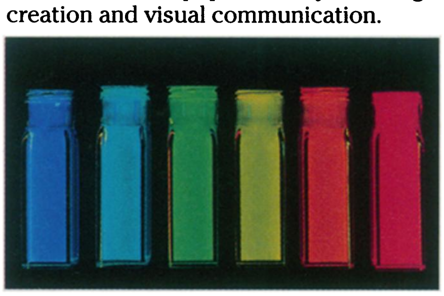
Each of Felice Frankel's photographs portrays some fragment of the material world: the rumpled face of a swollen gel, the fluorescent glow of encapsulated nanocrystals, colonies of rust encrusting a slab of weathered iron, a spidery microelectrode splayed across a surface, and much more.

The exquisite details, shadowed nuances, and vivid hues of Frankel's portraits of materials offer a stark contrast to the often murky, monochromatic images squeezed into the drab, text-laden pages of scientific journals. Her photographs portray science through an artist's lens. They unveil a rich store of information valuable to both researcher and casual viewer.

Photographs and illustrations can be both informative and aesthetically pleasing, Frankel maintains. Moreover, "the process of generating an image helps you understand the science better," she says.

As an artist-in-residence at the Massachusetts Institute of Technology, she has collaborated with chemists, engineers, and other researchers to demonstrate the benefits of paying close attention to the creation of images as part of laboratory work.

Earlier this year, Frankel received a grant from the National Science Foundation (NSF) to formulate guidelines and produce a handbook aimed at helping students develop proficiency in image creation and visual communication.



Vial Light. *Each container holds a suspension of cadmium selenide nanocrystals of a different diameter. Ultraviolet light causes the nanocrystals to fluoresce, giving off a color that depends on particle size, which ranges from 2 to 8 nanometers.*

Room to Grow. *Colonies of bacteria produce complex patterns as they grow out from a starting point (bottom) in a gel containing nutrients. Visible terraces form when a population of bacteria reaches a certain size and a portion of that colony moves away to stake out a new, nutrient-rich region. Cycles of expansion and stationary growth create the scalloped appearance.*

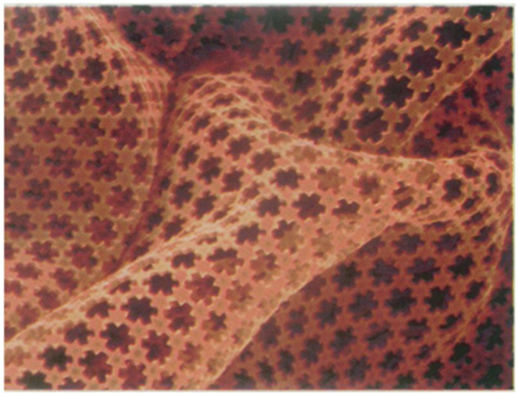
"The motivation here is to elevate the skills of the next generation of researchers so that they can communicate better amongst themselves and with the general public," says J. Kim Vandiver, who heads MIT's Edgerton Center, where Frankel is a research scientist.

In a world awash with images—on television, in magazines, and across the World Wide Web—it may seem somewhat paradoxical that visual expression requires special attention.

"We have more and more stuff out there, but visual images are still not properly valued," says art historian Barbara

Maria Stafford of the University of Chicago. "Intelligently created images are not merely illustrative or just entertaining. They are also deeply rich in information, and they can appeal to a variety of audiences at many different levels."

In most scientific publications, however, illustrative material accompanying a research paper tends to have a low priority, and researchers rarely go to extra trouble to create images that are appeal-

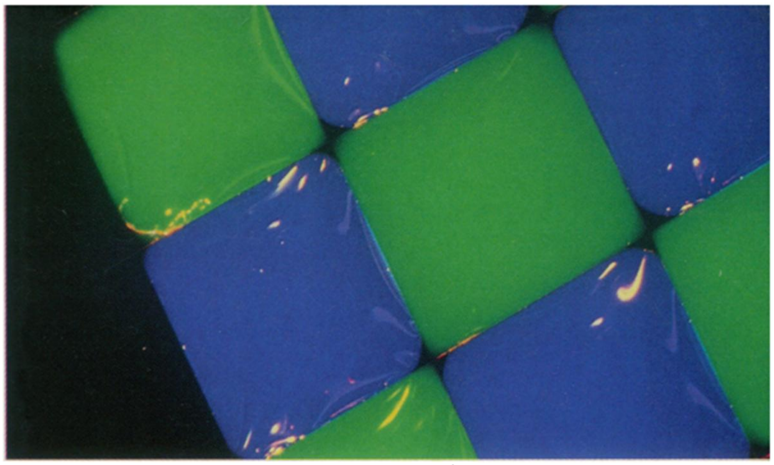


Plastic Microlace. *Made of molded plastic, this fabric's narrowest links are about 1 micrometer wide. The original black-and-white scanning electron microscope image was digitally colored, and the colored version appeared on the cover of the Aug. 17, 1995 NATURE.*

ing. Moreover, some publishers discourage the use of color illustrations or photographs by charging high fees for their inclusion, says chemist Moungi G. Bawendi of MIT.

Indeed, such practices may partially reflect a long-standing prejudice against the visual and a belief that "looking" is an essentially shallow, even corrupting, activity, Stafford notes.

In contrast, she cites scientific and medical illustrations created during the 18th century as prime examples of the successful integration of visual with textual material and of novel formats for presenting different types of information. "We can learn much from such examples," Stafford says.



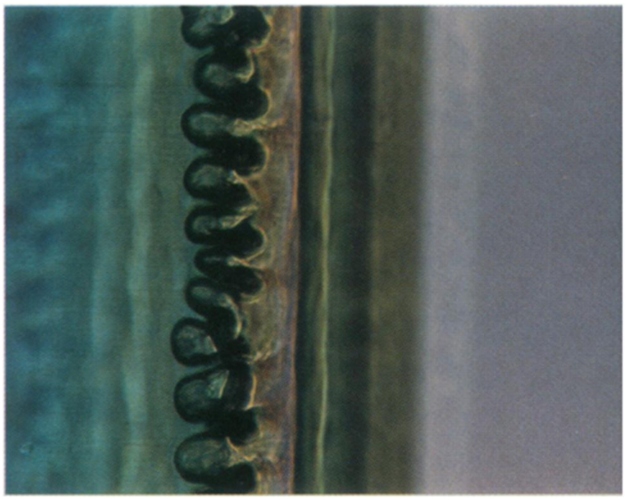
Grid Drops. *Droplets of water containing fluorescent dyes create a striking checkerboard pattern when placed on square patches of a water-attracting material separated by 1-micrometer-wide strips of a water-repellent substance and subjected to ultraviolet light. The image appeared on the cover of the Sept. 4, 1992 SCIENCE.*

Together with physicist Robert N. Beck of Chicago's Center for Imaging Science, Stafford has been developing and teaching an undergraduate course aimed at getting science students to think about imaging and the information conveyed by images—whether they are photographs, brain scans, or weather maps.

"I see the course as an introduction to the idea of there being two different ways of knowing about ourselves and the world around us—through language and through visual materials," Beck says. "My hope is that the students will take seriously the power of both methods to convey knowledge—as well as to convey falsehood."

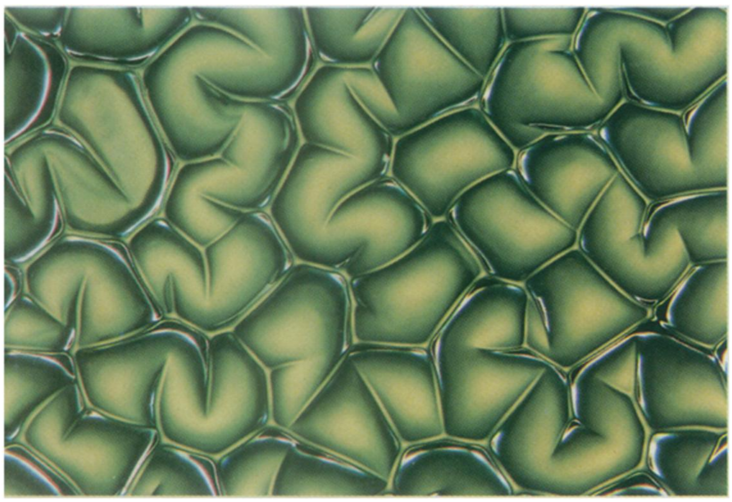
Frankel's emphasis is on the camera as a tool for acquiring images that illuminate the science without distorting or obscuring it. "By addressing the aesthetic component, you actually add data," she contends. "[The images] also allow you to get the concept without needing to know the language."

The resulting photographs become a legitimate part of the scientific investigation rather than just decorative trophies, she adds. Such images play a significant role in the data collection process and later in communicating the findings.



Sticky Stuff. *As pressure-sensitive, transparent tape is slowly pulled from a solid surface, the adhesive polymer at the interface develops a distinctive fingering pattern that depends on the strength of the interaction between the adhesive and the surface.*

"[Frankel] has shown us how important photographs of the actual material can be," Bawendi says. The trouble is that few scientists and engineers have the training and experience needed to evaluate and improve their imaging and visualization techniques, so Frankel's expertise and artistry are in great demand.



Gel Jumble. *Displaying features about 1 millimeter wide, the surface of a swelling gel crumples into a tortured landscape.*

Frankel had been a photographer of landscapes and architecture for about 20 years before returning to science, which she had studied many years earlier as a biology major. In 1991, she received a fellowship that allowed her to spend a year at Harvard University.

During that sojourn, she worked with chemist George M. Whitesides and his colleagues, helping them photograph various microscopic structures. One of her photographs appeared on the cover of the Sept. 4, 1992 SCIENCE.

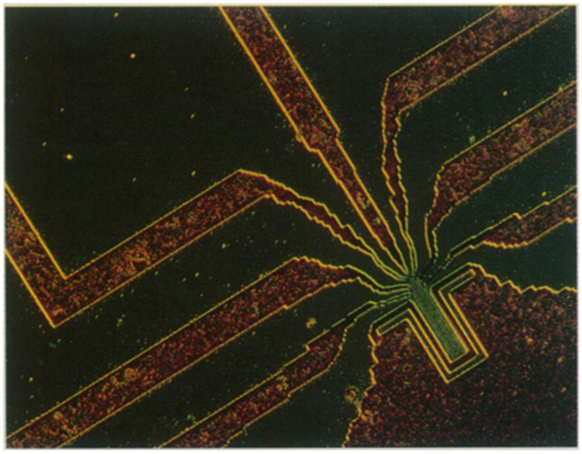
When Frankel went to MIT, her enthusiasm for science and her fascination with materials, in particular, led her to seek out other scientists and engineers who would let her work with them. Now, she has an extensive portfolio of images representing a wide range of materials and processes.

The recently published book *On the Surface of Things: Images of the Extraordinary in Science* (1997, San Francisco: Chronicle Books) features a selection of her scientific photographs, along with commentaries written by Whitesides.

In her collaborations with scientists, Frankel has learned a great deal about science and about the special needs and constraints of scientific photography, especially the necessity for technical accuracy. She has developed a strong interest in formulating standards for visualization.

Her collaborators have also benefited. "Pictures help you do science," Frankel says. "They encourage thinking."

To photograph a physical system, it's often necessary to consider such factors as color, texture, and lighting. "Each time we find ourselves thinking about the system in a way that requires a greater degree of control, we learn something about it," Whitesides says.



Spider Pipes. *The solid metal wires of these microelectrodes, outlined in gold, serve as conduits for electrons, which can leak into the liquid that covers the wires.*

Such requirements can also lead to useful observations that might not otherwise have been made. For example, when Whitesides and his coworkers were studying drops of water separated by very thin barriers, they introduced dyes into the liquid to make the photographs more interesting.

"Putting in dyes enabled us to think about the question of whether there were small channels that allowed the fluids to leak from one drop to another without necessarily making a visible bridge," Whitesides says. "As far as we could see, there was no such thing, but we had a new piece of information."

Frankel's NSF project gives her a chance to see how much of the art she brings to scientific photography and to imaging in general can be readily conveyed to students. "It's technically very demanding and not at all obvious how to take these pictures," Whitesides notes.

When Frankel's project is completed, students who go through her course or read the resulting handbook should be much better able to select appropriate methods and equipment to document their research.

In addition, "I think it's useful to teach students how to look at something for its visual qualities," Whitesides says.

Another issue is fidelity. "One of my principal concerns is that visual materials in their present digital form can be readily manipulated," Beck says. "In the future, students are going to have to be trained to be as critical of visual materials as they are now trained to be critical of verbal materials."

Frankel herself appreciates the dangers. "As an architectural or landscape photographer, I knew how to make a wonderful picture out of something not so wonderful," she says.

In scientific work, accuracy is paramount. It's the combination of truth and beauty that merits attention. □

Earth Science

From a meeting in San Francisco of the American Geophysical Union

Pollution surge from new Chinese cars

As residents of China trade in their bicycles for cars, the resulting tailpipe pollution will harm the entire western Pacific and have indirect global ramifications, according to calculations by an atmospheric chemist and his colleagues.

Only a few million people in China now own private cars, but that number could rise to 400 million in 50 years, as the country's population tops 1.5 billion, says Scott Elliott of Los Alamos (N.M.) National Laboratory. Starting with these estimates, Elliott analyzed how the exhaust would spread across the country and out over the Pacific. His initial report appeared in the Nov. 1 GEOPHYSICAL RESEARCH LETTERS.

A computer simulation of air currents shows China producing a broad plume of ozone pollution, generated by the nitrogen oxides in car exhaust. "We compute that cars would bathe the entire western Pacific in ozone, which means that Korea and Japan would have ozone levels comparable to [those in] Los Angeles on a bad summer day," says Elliott. Ozone from China could even reach North America.

The additional cars would also contribute significantly to greenhouse warming. Elliott estimates that global emissions of carbon dioxide could rise as much as 30 percent.

Thomas E. Graedel, an industrial ecologist at Yale University, notes that Chinese motorization would not occur in isolation. Elliott's calculations do not take into account the massive development that China must undergo before it could produce and support such a large increase in the number of cars, he says.

Elliott adds that China is only one of many countries that will expand their automobile fleet in the next half century. *—R.M.*

California volcano starts to stir

Soon after the debut of *Dante's Peak*, a fictional film chronicling a volcanic eruption in the Pacific Northwest, nature provided some unanticipated publicity for the movie. This summer, a real volcanic site in eastern California began generating many earthquakes even as instruments picked up signs that the ground there was expanding. Since then, the region has spawned a handful of house-rattling jolts and 8,000 small tremors above magnitude 1.2, reports David P. Hill of the U.S. Geological Survey (USGS) in Menlo Park, Calif.

The seismic activity, called a quake swarm, remained relatively minor through the spring and summer but took off in October, culminating with three jolts approaching magnitude 5 in late November. The earthquakes have centered on the southwest side of the Long Valley caldera, a 30-kilometer-long oval depression on the eastern flank of the Sierra Nevada. Overlapping the ski town of Mammoth Lakes, Calif., the caldera formed 760,000 years ago when an eruption of magma caused the crust to drop by 2 km.

Over this year, instruments have detected the ground inside the caldera warping upward by 5 centimeters, a dramatic jump over the gradual deformation seen in the last few years. The dome-shaped region has risen 70 cm since 1980.

Geoscientists have been monitoring the seismic unrest and ground movement closely, looking for signs that magma is squeezing up through the crust toward the surface, perhaps portending an eruption. So far, no clear evidence of magma movement has emerged, and the USGS assessment of eruption risk remains on the lowest level of a four-tier alert system.

Scientists at USGS have seen even stronger quake activity at Long Valley twice before, in 1980 and 1983, without any eruptions. In 1982, the agency prepared a notice of potential volcanic hazard that alienated many residents of Mammoth Lakes and turned into a public relations fiasco. Since then, there have been occasional smaller quake swarms and quiet intervals. "These can go on for decades or centuries without an eruption. What we have to do is keep watch," says Hill. *—R.M.*