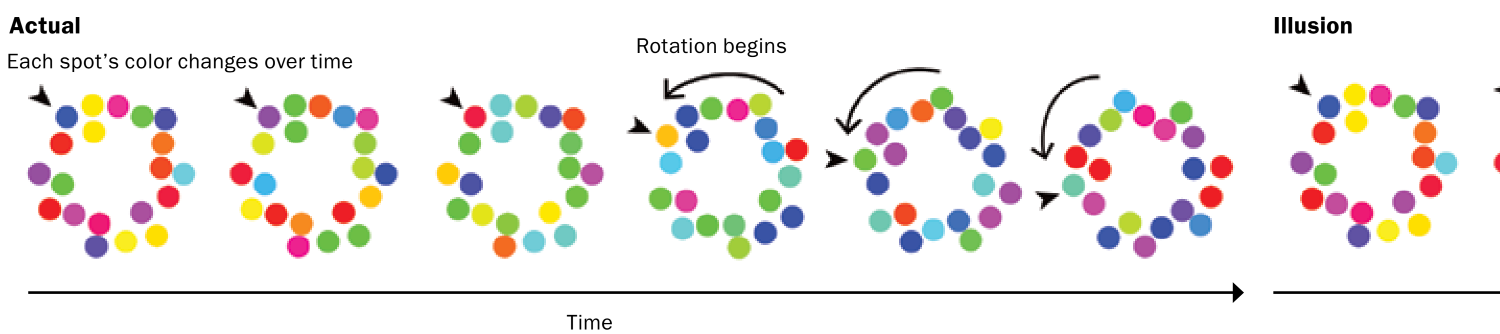
MIND-WARPING VISIONS

10 BRAIN TWISTERS COMPETE TO BE THE BEST ILLUSION OF 2011

BY STEPHEN L. MACKNIK AND SUSANA MARTINEZ-CONDE

Jordan Suchow came to three rapid-fire conclusions as he watched his Macintosh laptop plummet toward the floor. First, in approximately 300 milliseconds he was going to be in a heap of trouble—the machine had been given to him by his thesis adviser, George Alvarez of Harvard University. Second, hoping against all hope, he decided that Harvard could probably afford to buy him a new computer. Third, he realized that the most important observation of his life was unfolding right in front of him as his laptop accelerated toward the parquet: the onscreen doughnut that he had programmed to scintillate appeared to have stopped doing so.

COURTESY OF HÉCTOR RIEIRO *Barrow Neurological Institute*



Suchow's Ph.D. research project on cognition and attention had required him to program a visual display in which every element changed continuously, hence the scintillating doughnut. While working on the project at home, Suchow pulled his Mac from a coffee table to his lap. During the transfer, he noticed that the cycling of the doughnut's colors seemed to slow down. Startled, he dropped the machine altogether and was fascinated to see the color cycling cease completely as the doughnut fell.

His accidental discovery won the top prize at the 2011 Best Illusion of the Year Contest. A professional wrestling match of the minds, the contest barraged the audience's brains with perceptual pile drivers, mental Mongolian chops and cognitive clotheslines—moves designed to conjure up a reality that does not actually exist.

Inside your brain, you create a simulation of the world that may or may not match the real thing. Your "reality" is the result of your exclusive interaction with that simulation. When you experience an illusion, your perception differs from physical reality in substantial ways. You may see something that is not there, or fail to see something that is there, or see something differently from the way it actually is. Suchow's visual neurons failed to see the doughnut's scintillating colors, even though they were most definitely there.

Yet illusions are not the failures of perception that they are often portrayed to be. Rather they can result from evolutionary adaptations. Sometimes illusions occur because of shortcuts that your brain takes to help you survive and

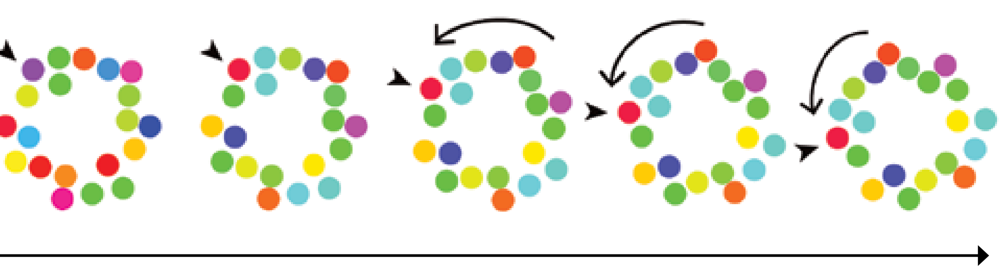
The first-, second- and third-place trophies (*right*) awarded to the contest winners (*above*) are sculptured illusions created by Italian artist Guido Moretti.

COURTESY OF JAN DREWES (*top*); COURTESY OF INNA TSIRLIN (*bottom*)

thrive. They allow you to make lightning-fast assumptions that are technically wrong but helpful in practice. For example, you may underestimate or overestimate distances, depending on various contextual cues. In 2007 psychologists Russell E. Jackson of California State University, San Marcos, and Lawrence K. Cormack of the University of Texas at Austin reported that observers estimated the height of a cliff when looking down from the top to be 32 percent greater than when looking up from its base. Given that accidents are more likely to happen while climbing down rather than up, this miscalculation may make you descend cliffs with greater care, reducing your chances of falling.

Illusions also offer a window into how our neural circuits create our first-person experience of the world. Suchow's doughnut is just one of this year's top illusions that rely on a phenomenon called silencing, in which changes go unseen because the motion of something else captures all the viewer's attention. Silencing illusions are reminiscent of the magician's adage that "a big motion covers a smaller motion."

As with most of the top illusions of the past few years, most of the 2011 winners are "dynamic"—that is, they rely on moving images to work their magic. Such images are difficult to reproduce on the printed page; instead this article reveals the secrets behind the illusions. We en-



SILENCING COLOR: In this winning illusion, the color of every dot in the doughnut changes over time. When the doughnut rotates, the colors continue to change, but viewers do not notice these changes—perhaps because the motion stifles awareness of the shifting colors—even though they can accurately report the current color of the dots if asked.

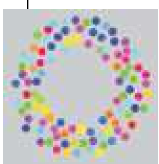
WHEN YOU PAY ATTENTION TO A PART OF A VISUAL SCENE, THE SURROUNDING MOTION IS SUPPRESSED.

courage you to view the winning illusions, including two that cannot be shown here, in their animated form on the Web at http://illusionoftheyear.com/2011.

Illusions competing in the Best Illusion of the Year Contest must be novel: that is, previously unpublished or published within the past year. An international panel of experts selects the 10 illusions that are the most counterintuitive, spectacular, beautiful and significant to the understanding of the human mind and brain. The creators are invited to present their awe-inspiring brain twisters at a contest event where the audience votes to choose the winners of first, second and third prize: regarded as the "Oscars" of illusion.

Anyone can submit an illusion to the competition—scientists, artists, software designers, mathematicians or creative people from any field. Instructions are posted at http://illusionoftheyear.com/submission-instructions. The Best Illusion of the Year Contest's eighth annual gala, which is free and open to the public, will be held on May 14, 2012, at the Philharmonic Center for the Arts in Naples, Fla. Please join us and vote for the best illusion of the year! M

THE ROUNDS OF SILENCE



Like a rainbow-sprinkled doughnut, the eye-popping illusion created by Suchow and Alvarez claims your full attention. If you pick out a single dot from the crowd, you will see it change color over time … until the entire doughnut starts to rotate. Then the color cycling appears to stop. In fact, the color cycling never ceases. Somehow the rotation of the doughnut suppresses your perception of the color change. This "silencing" effect also works if you do not rotate the doughnut but instead view the colorful display as you hurtle down a roller coaster. Or fling your laptop into a gravity well while contemplating both the image on the screen and the benevolence of your boss.

The biological explanation for this illusion is unknown, but it might be connected to the neural circuits for attention that we discovered in collaboration with the laboratories of neuroscientists Jose-Manuel Alonso of the S.U.N.Y. College of Optometry and Harvey Swadlow of the University of Connecticut. Our results, published in 2008, showed that motion-sensitive circuits in the visual area of the brain known as V1 are intimately linked to our attentional spotlight, so that when you pay attention to a specific part of a visual scene, the surrounding motion is suppressed. In the case of Suchow and Alvarez's silencing illusion, motion may attract the observer more powerfully than color swaps, causing suppression of the latter.

http://illusionoftheyear.com/2011/silencing-awareness-of-change-by-background-motion

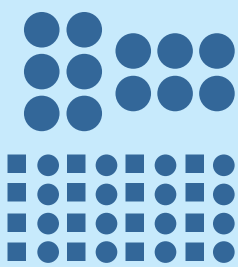
THE GERMAN GESTALT

Peter Thompson of the University of York in England, a leader in the field of visual perception and illusions, emceed the gala. He announced one contestant by asking the audience, "Where would we be without fun and laughter? Germany! Which is where this next illusion comes from." Psychologists Erica Dixon and Arthur Shapiro, both Americans from American University in Washington, D.C., and Kai Hamburger, an actual German from the University of Giessen, call their illusion grouping by contrast. It introduces a stunning new facet to the Gestalt laws originally formulated by German psychologists.

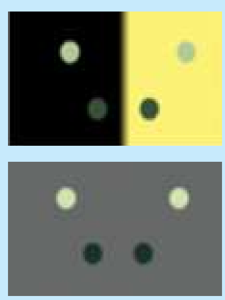
As Dixon explained in her onstage presentation, two of these laws are relevant to the illusion that her team created: the law of proximity, in which objects near one another tend to be grouped together, and the law of similarity, in which objects similar to one another are also clustered. Dixon and her colleagues discovered a new grouping principle that is even more powerful than the previous two laws combined. In their grouping by contrast illusion, the researchers showed that the brain tends to bundle objects with similar absolute contrasts, a propensity that was previously unknown.

Absolute contrast is the magnitude of an object's contrast with respect to its background, irrespective of whether the object is light on dark or dark on light. Surprisingly, the brain prefers to group objects by their absolute contrast rather than by their proximity or similarity, or both these traits combined. When you see four spots, two in the top row blinking together from dark to light and two in the bottom row blinking in opposite phase, with a background that is light on the right and dark on the left, the brain groups the spots along the diagonal—even though the spots that are both closest and most similar are across rows. The brain prefers the diagonal pairing because those dots share the same level of contrast—the difference in the brightness between every dot and its background. This new and critically important observation will no doubt guide research into how the brain computes object categorization. The work won second prize at the 2011 contest.

http://illusionoftheyear.com/2011/grouping-by-contrast



GESTALT LAWS: The law of proximity states that objects near one another, such as the circles at the upper left, appear to form a group—in this case, in columns and rows. The law of similarity states that objects that are similar, such as the squares shown at the lower left, seem to belong together.



GROUPING BY CONTRAST: The viewer's brain insists on pairing blinking dots diagonally when they share the same level of contrast with their background (*upper right*). With this contrast removed, the brain pairs the dots by proximity and similarity (*lower right*).

LEFT TO RIGHT: FROM "MOTION SILENCES AWARENESS OF VISUAL CHANGE," BY JORDAN W. SUCHOW AND GEORGE A. ALVAREZ, IN *CURRENT BIOLOGY*, VOL. 21, NO. 2; JANUARY 25, 2011. REPRINTED WITH PERMISSION FROM ELSEVIER; SCIENTIFIC AMERICAN MIND; COURTESY OF ERICA DIXON AND ARTHUR SHAPIRO *American University* AND KAI HAMBURGER *University of Giessen*

THE LOCH NESS AFTEREFFECT

Mark Wexler of the University of Paris V in France took third-prize honors with his Loch Ness aftereffect. He named it after a classic illusion that was known to the ancient Greeks and rediscovered in 1834 by Robert Addams at the Falls of Foyers, which are the waterfalls that feed Loch Ness in Scotland. Addams noticed that after he stared at the waterfalls for a while, stationary surfaces, such as the rocks and vegetation beside the falling water, appeared to drift upward.

In Wexler's illusion, the viewer stares at a red dot surrounded by a rotating ring of dashes. Suddenly the ring jumps in the opposite direction with a rapid rotation, before continuing to turn slowly in the original direction again. Wait—the ring is not really jerking backward at all—that's all you, baby! In reality, the ring's elements are simply reassorted at random. Unlike the illusory motion described by Addams, which is slower than the real movement that induces it, Wexler's faux motion is 100 times faster than the inducing movement.

Wexler's illusion is called an aftereffect because you perceive it once the physical motion stops—for instance, when you see spots after a camera flash—but here it works specifically for motion-sensitive neurons. Wexler says the illusion is related to how the brain matches the starting points of moving objects to the next points along the motion trajectory. Presented with a burst of random visual noise, the brain finds no consistent correspondences and is forced to take a guess at the best possible matches, which happen to be far away because of the randomization, resulting in the observer's perception of fast motion. Only future research will determine the specific neural underpinnings of this effect.

http://illusionoftheyear.com/2011/the-loch-ness-aftereffect

JUMPING RING: The dashes that make up a rotating ring are periodically rearranged in random fashion. The viewer's brain, unable to match the new arrangement with the expected trajectory, perceives this as a rapid backward rotation.

MASK OF LOVE

Courtney Smith presented the mask of love illusion, created in collaboration with Gianni Sarcone and Marie-Jo Waeber of the Archimedes Laboratory Project in Genoa, Italy. A young girl in a Venetian mask pines for love. Or perhaps she is beyond the yearning period and has moved on to kissing. This type of illusion is called bistable because, as in the classic face-vase illusion, you may see either a girl or a couple, but not both at once. The visual system tends to see what it expects to see—only one mask is present, so you are much more likely to see a single face on first glance.

The illusion was discovered in an old photograph of two lovers sent to the Archimedes Laboratory. Sarcone, the leader of the group, saw the image pinned to the wall and, being nearsighted, thought it was a single face. After donning his eyeglasses, he realized what he was looking at. The team later paired the picture of the lovers with the beautiful Venetian mask. Luck does favor the prepared mind ... and the nearsighted.

http://illusionoftheyear.com/2011/mask-of-love

SEEING DOUBLE: Most people initially see one face here because of the surrounding mask. But look again, and you'll see two.

COURTESY OF MARK WEXLER *University of Paris V (top)*; COURTESY OF ARCHIMEDES LAB PROJECT *(bottom)*

(The Authors)

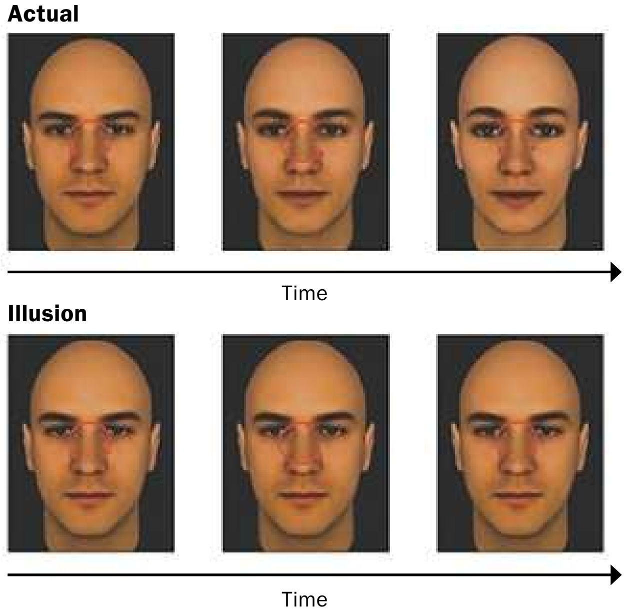
STEPHEN L. MACKNIK and SUSANA MARTINEZ-CONDE are laboratory directors at the Barrow Neurological Institute in Phoenix. They are authors of the recently published book *Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions,* with Sandra Blakeslee, now out in paperback (http://sleightsofmind.com). Their forthcoming book, *Champions of Illusion,* will be published by Scientific American/Farrar, Straus and Giroux.

HE OR SHE?

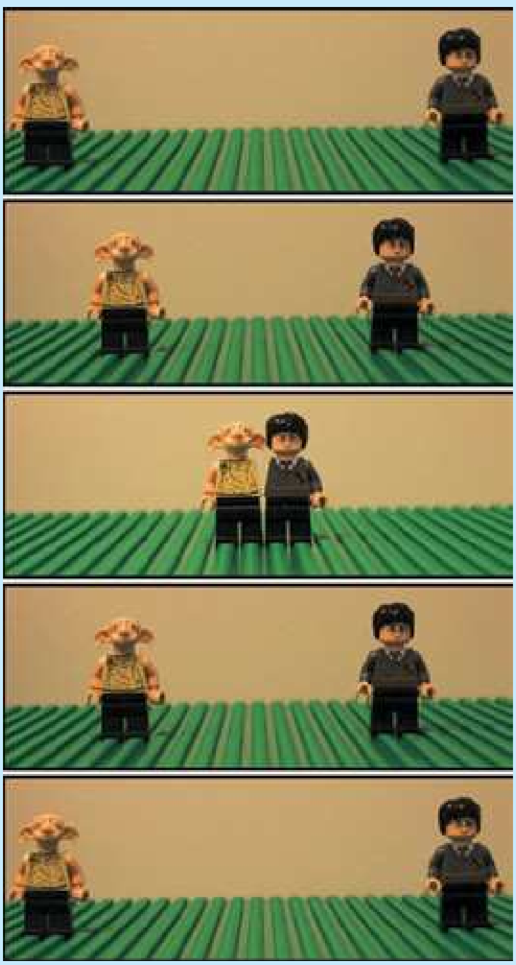
Rob van Lier and Arno Koning of the Donders Institute in the Netherlands asked the audience to keep their eyes on a circling red dot superimposed on a face. When the dot disappeared a short while later, the face morphed from that of an androgynous male to one that looks more female and then back to male. When the red dot reappeared for the audience to follow, the faces stopped morphing. In reality, the faces had morphed continuously the entire time and appeared unchanging only when viewers focused on the moving red dot. Van Lier demonstrated that the illusion also worked when he altered the emotions and the age of the faces and even when he used famous examples, such as Barack Obama's face changing between happy and sad expressions.

Just as with Suchow and Alvarez's silencing effect, the neural underpinnings of this illusion are unknown but could have their roots in how attention works in the brain. In this particular case, closely watching the moving dot may suppress neural activity in the fusiform gyrus, the part of the brain that processes faces.

http://illusionoftheyear.com/2011/the-more-or-less-morphing-face-illusion



TWO-FACED: The face in this illusion morphs over time, shifting from predominantly male characteristics to more feminine ones and back again. Viewers who focus on a circling red dot fail to see the face changing.



IN A BIND

Shapiro, who had a hand in the grouping by contrast illusion, developed a second illusion, this one with Gideon Caplovitz of the University of Reno. First, Shapiro showed two vertical bars, one red and one green, sweeping left and right across a screen. When the bars met in the middle of the screen, they changed colors and rebounded off each other, streaked back to the edge of the screen and bounced back to the middle. Shapiro asked the audience to look at a spot above the screen while paying attention to the bouncing bars. People "ooooohed" as they saw the bars once again collide, but instead of ricocheting the bars now seemed to pass through each other and retain their original color. Shapiro went on to show that the pass-through effect also works with textured, rather than colored, bars. He even demonstrated the illusion using Lego figurines of Harry Potter and his elf buddy Dobby, raided from his child's closet.

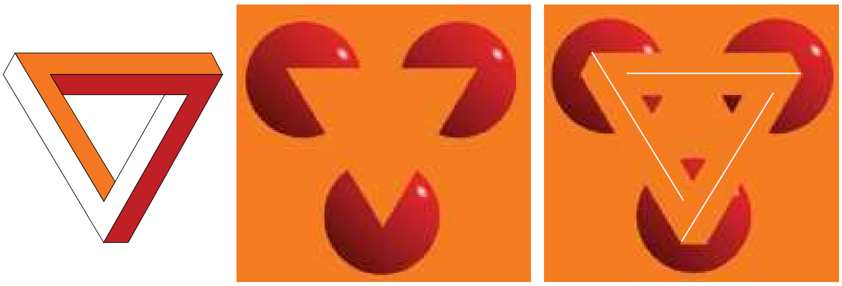
This little gem of an illusion helps us pick at the corners of what neuroscientists call the binding problem. The cortex (Latin for "bark," or "outer layer") of the brain is organized into areas that process particular types of information. Motor and cognitive processes take place in the frontal lobes of the brain, vision is in the back, and so on—with specific visual areas dealing with motion, color, texture and faces. If you look in the mirror and move your head from side to side cobra-style, somehow your brain must bind together the outputs of all the different areas involved in watching your moving face. Shapiro and Caplovitz's dramatic illusion shows that features bound to one object can rebind to a different moving object. The fact that the illusion varies in step with changes in the objects' location on the retina gives scientists a valuable clue for studying the neural basis of this effect.

http://illusionoftheyear.com/2011/the-exchange-of-features-textures-and-faces

JUST PASSING THROUGH: Harry Potter and Dobby bounce off each other as they meet midscreen. To a viewer focused on a spot above the screen, however, the toys appear to pass through each other—an example of how the brain can bind the features of one moving object to another.

COURTESY OF ROB VAN LIER AND ARNO KONING *Donders Institute* (*top*); COURTESY OF ARTHUR SHAPIRO *American University* AND GIDEON CAPLOVITZ *University of Reno* (*bottom*)

THE BRAIN MIGHT FILL IN NOT ONLY VISUAL INFORMATION BUT ALSO TACTILE SENSATIONS.



ANGLO-ITALIAN: Combining the Penrose triangle (*left*) with the Kanizsa triangle (*center*) yields an illusion that is simultaneously filled in and impossible (*right*).

TWO TRIANGLES

Christopher Tyler of the Smith-Kettlewell Eye Research Institute in San Francisco invented the magic eye illusions that were all the rage in the 1990s. In true academic tradition, of course, he never made a cent off them. At the 2011 contest he began his presentation by exhibiting the Penrose triangle, the quintessential impossible object, drawn in 1958 in its most familiar form by Roger Penrose of the University of Oxford. Tyler also displayed another famous triangle, first described by Italian psychologist Gaetano Kanizsa in 1955, which shows that the brain can create entire objects by filling in missing information. Tyler wondered whether he could integrate the two perceptual traditions. When he laid the outline and inner crossbars of the Penrose triangle over the three red balls making up the Kanizsa triangle, he discovered that the brain will fill in even impossible figures.

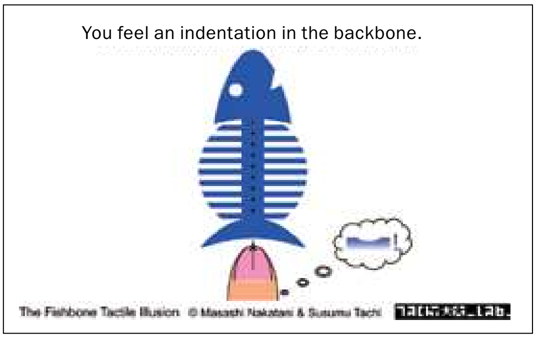
Tyler's illusion reveals that our brain constructs the feeling of a global percept—an overall picture of a particular item—by sewing together multiple local percepts. As long as the local relations among surfaces and objects follow the rules of nature, our brain does not seem to mind that the global percept is impossible or that its local features contain only the sparsest information.

http://illusionoftheyear.com/2011/impossible-illusory-triangle

THE MAGIC TOUCH

The first tactile illusion ever presented at the contest gives you a very fishy feeling. Masashi Nakatani of Keio University in Japan, costumed in spearfishing attire, passed out business cards embossed with ink in the shape of a stylized fish. With the flourish of a magician, Nakatani approached emcee Thompson onstage and told him, "Rub your finger up and down the spine. Up and down the spine. You feel a groove there? But ... there ... is ... none!" Thompson rubbed the fish's spine as instructed. "How do you feel?" Nakatani asked. "I feel dirty for feeling up this fish," Thompson deadpanned. "But I do feel a groove here."

Nakatani was intrigued by the possibility that the brain might fill in not only visual information but also tactile sensations. He thought he could create a texture that was not a circle but would feel like one. The fishbone pattern (without a head or tail) was one of many botched attempts. Disappointed, Nakatani took the sample to a senior colleague, Susumu Tachi, to describe his failure. Tachi agreed that the texture did not feel like a circle, but he noticed a central groove where there was none. He encouraged Nakatani to change his dissertation project to study the fishbone illusion full-time. By testing a variety of configurations and textures, Nakatani and his colleagues were able to determine that the illusion arises from how tactile receptors in your skin compare smooth and rough textures: your brain interprets the smooth spine to be lower than the rough ribs of the fish—and you're hooked.



FISHY FEELING: Rubbing your finger over a ribbed pattern gives the illusion of a grooved spine, thanks to the difference between the raised and flat textures.

http://illusionoftheyear.com/2011/fishbone-tactile-illusion

(Further Reading)

- **105 Mind-Bending Illusions.** Special edition on perception. *Scientific American,* Vol. 18, No. 2; Summer 2008.
- **Task Difficulty Modulates the Activity of Specific Neuronal Populations in Primary Visual Cortex.** Y. Chen, S. Martinez-Conde, S. L. Macknik, Y. Bereshpolova, H. A. Swadlow and J. M. Alonso in *Nature Neuroscience,* Vol. 11, No. 8, pages 974–82; August 2008.
- **169 Best Illusions.** Special issue. *Scientific American Mind,* Vol. 20, No. 1; Summer 2010. Voted a top-10 science news story for 2010 by the readership of *Scientific American.*
- **Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions.** Stephen L. Macknik and Susana Martinez-Conde, with Sandra Blakeslee. Henry Holt and Company, 2010.

SCIENTIFIC AMERICAN MIND; COURTESY OF CHRISTOPHER W. TYLER *Smith-Kettlewell Eye Research Institute (top);* COURTESY OF MASASHI NAKATANI AND SUSUMU TACHI *Keio University (bottom)*