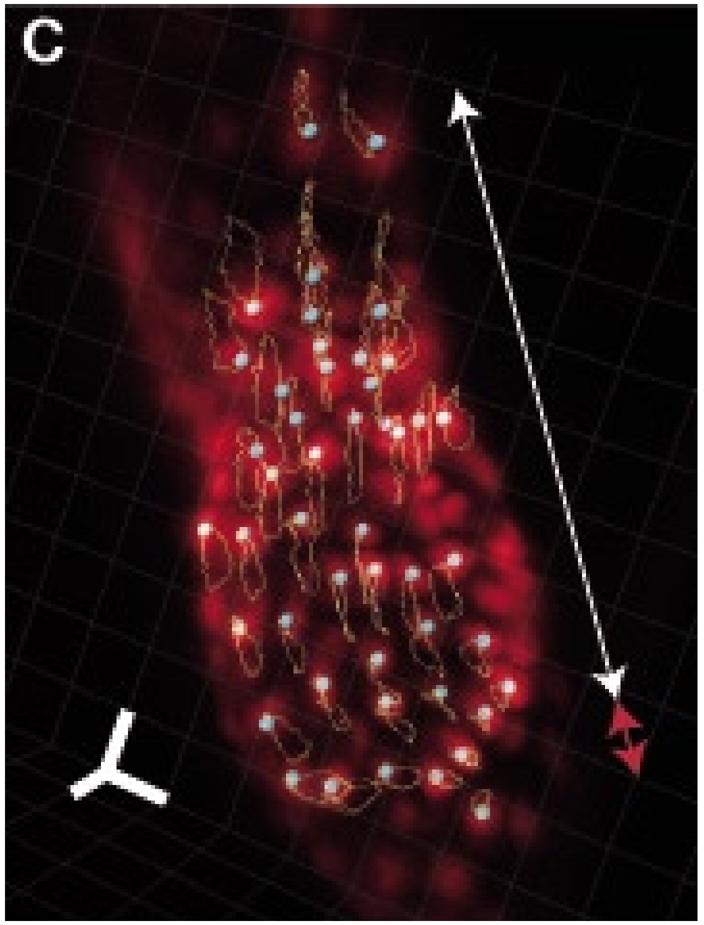
STILL NEED A CLEVER TITLE



A. Forouhar, et. al., *Science*, vol. 312, pp. 751–753. © 2006, American Association for the Advancement of Science.

A 3-D reconstruction of a 26-hour-old zebrafish embryo's heart tube. The glowing red cells are the myocytes, and the three-dimensional trajectory traced by the center of each cell (colored dots) over two successive heartbeats has been drawn in as well. The inflow tract is at the bottom, and the red double-headed arrow shows where the "pacemaker" cells are located. The 3-D scale bar in the lower left corner is 20 microns, or millionths of a meter, along each leg.

Looking at an adult human heart and an embryo's heart, you'd never guess that the former developed from the latter. While the adult heart is a fist-shaped organ with chambers and valves, the embryo heart is tubular. It's been assumed that the embryonic heart pumps by peristalsis, like your intestines do—a method of action similar to squeezing a tube of toothpaste. But Caltech biologists and engineers leading an international team have shown that the tube is actually a suction pump that works much like the left ventricle in the mature heart.

Says Mory Gharib (PhD '83), Caltech's Liepmann Professor of Aeronautics and Bioengineering, "Embryonic and adult hearts look like two different engineers designed them separately. But this study shows there is continuity to the pumping mechanism."

Gharib's graduate student Arian Forouhar (PhD '06) and the other researchers used confocal microscopes in the Biological Imaging Resource Center (BIRC) located in Caltech's Beckman Institute to do time-lapse photography of embryonic zebrafish. Zebrafish were chosen because they are essentially transparent, thus allowing for easy viewing, and because they develop completely in only a few days.

Scott Fraser, Caltech's Rosen Professor of Biology and professor of bioengineering and the principal investigator of the BIRC, notes that "this pumping mechanism had not been noticed before because of the limitations of imaging technology. Now we have a device that is 100 times faster than the old microscopes, allowing us to see things that previously would have been a blur. Now we can see the motion of blood and the motions of vascular walls at very high resolutions."

The time-lapse photography showed that the embryo heart uses a valveless pumping action known as hydroelastic impedance pumping, in which a handful of cells called myocytes, usually situated near the entrance of the heart tube, contract to initiate a series of forward-traveling elastic waves that eventually reflect back from the tube's far end. At a specific range of contraction frequencies, these waves constructively interfere with one another to generate an efficient dynamic-suction region at the tube's outflow tract. This mode of action is also noteworthy because a small number of "pacemaker" cells are sufficient to sustain circulation.

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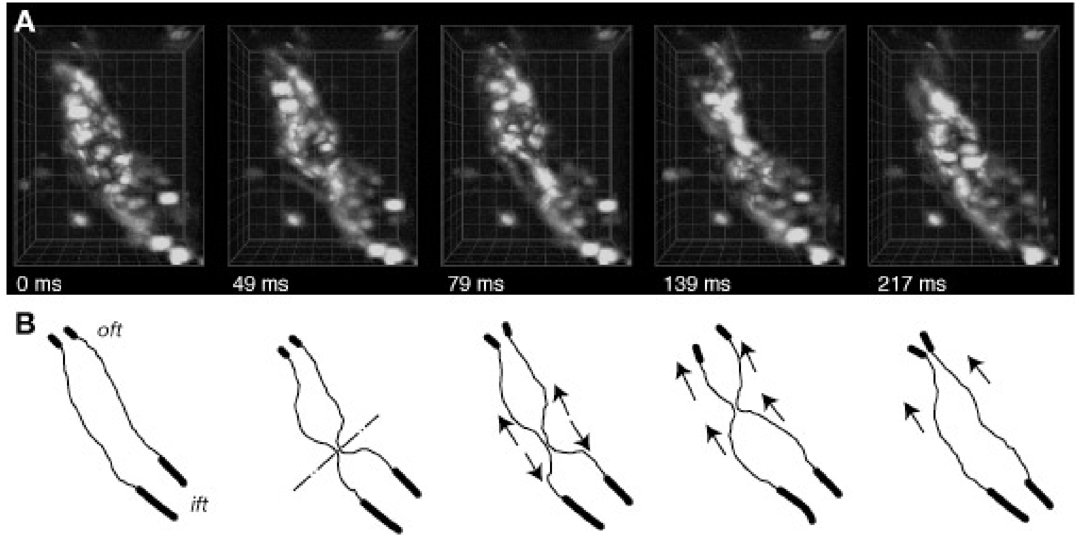


Top: In this set of six 3-D reconstructions during a single heartbeat, the myocytes appear as white blobs and the yellow lines mark the heart wall, or endocardium. The grid size is 20 microns. Bottom: The red and blue arrows show the paths of the wave fronts as they spread out from the contraction site. Changes in heart tube diameter and elasticity at the inflow tract (ift) and outflow tract (oft) reflect the waves back on themselves to form the low-pressure "suction bolus" that pumps the blood. Elapsed times are shown in millseconds.

"The heart is one of the few things that makes itself while it's working," Fraser says. "It likely begins forming its structures when it's still a tiny tube the diameter of a hair." "This allows us to reconsider how embryonic cardiac mechanics may lead to anomalies in the adult heart, since impairment of diastolic suction is common in congestive heart-failure patients," says Gharib. "One of the most intriguing features of this model is that the mechanical stimuli from only a few contractile cells may guide later stages of heart development," says Forouhar.

According to Gharib, this simplicity of construction could guide the design of devices to gently move blood, drugs, or other biological fluids. The findings could also lead to new treatments of heart diseases that arise from congenital defects, and, says Fraser, demonstrate the promise of advanced biological imaging techniques for the future of medicine.

The work is described in the May 5 issue of *Science*. In addition to Forouhar, Gharib, and Fraser, the other authors are Michael Liebling, a postdoc in the BIRC; bioengineering grad students Anna Hickerson (BS '00, PhD '05) and Abbas Nasiraei Moghaddam; Huai-Jen Tsai of National Taiwan University's Institute of Molecular and Cellular Biology; Jay Hove of the University of Cincinnati's Genome Research Institute; and Mary Dickinson of the Baylor College of Medicine. Movies of the beating heart can be seen at http://www.gharib.caltech.edu/cardiovascular_research/index.html under "Embryonic Heart." **[I don't see 'em yet.]** □—*RT*

THE EYES HAVE TREES

If a tree falls in the forest and lands next to another one, does a caveman invent the letter L? He might. According to Caltech postdoc Mark Changizi, a theoretical neurobiologist, letters and other commonly used symbols may have their particular shapes because "these are what we are good at seeing."

In essence, he says, the basic elements of the Greek and Roman alphabet, plus the Chinese, Persian, and 96 other writing systems that have been used through the years are visual repetitions of common sights, just as onomatopoeias such as 'bow wow" are aural repetitions of common sounds. "Evolution has shaped our visual system to be good at seeing the structures we commonly encounter in nature, and culture has apparently selected our writing systems and visual signs to have these same shapes," says Changizi, the lead author of a study published in *The American Naturalist*.

Engineers have known for some time that the best way to create a computer-vision system that recognizes objects is to identify where lines meet. In other words, a robot navigating a room sees the conglomeration of contours in a corner by its "Y" shape, and sees a wall because of its "L" junction with the floor. Says Changizi, "It struck me that these junctions are typically named with letters, such as 'L,' 'T,' 'Y,' 'K,' and 'X,' and that it may not be a coincidence that the shapes of these letters look like the things they really are in nature."

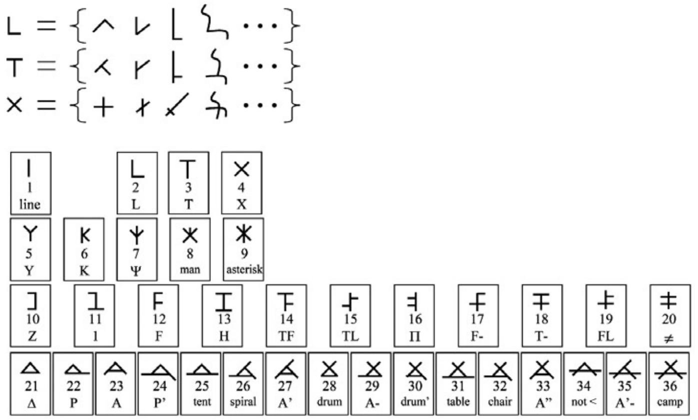
So Changizi used topology to group letter and symbol shapes. An "L" can be turned into a "V," for example, just by bending it, so they are topologically the same. Cutting line segments is not allowed, nor is changing the ways in which they intersect. He ended up with a catalog of 36 shapes made of two or three line segments, which he ranked according to how frequently they occur in things that ancestral humans would have seen millions of years ago, in pictures across many cultures that he took from *National Geographic*, and in computer-generated architectural forms.

It turns out that the common shapes are precisely those that frequently show up in the letters of various writing systems, in company logos, and in symbolic systems such as musical notation. The forms not found as frequently in nature, by contrast, show up less often.

"It's striking that symbols that are intended to be seen have high correlations to natural forms," Changizi says. "Company logos, for example, are meant to be recognized, and we found that logos have a high correlation. Shorthand systems, which are meant to give a note-taker speed at the expense of a commonly recognizable system of symbols, do not. Figures that are intended to be 'read' seem to be selected because they are easy to see rather than easy to write. They're for the eye."

In addition to Changizi, the authors are Professor of Biology Shinsuke Shimojo and undergrads Qiong Zhang and Hao Ye (BS '06). □—*RT*

M. Changizi, et. al., *The American Naturalist*, vol. 167, no. 5. © 2006, University of Chicago Press.



Changizi's periodic table of letter topologies.

IF THIS IS AN E-ARTICLE ONLY, IS THIS CITAITON OK?

TMT Is A-OK

The Thirty Meter Telescope, or TMT, has passed its conceptual design review by an independent panel of experts. Now in detailed design, the TMT will be the world's largest telescope. It consists of a primary mirror with 738 individual 1.2-meter segments that span 30 meters in total, three times the effective diameter of the current largest telescopes. All of the segments will be under exquisite computer control so that they work together as a single mirror.

The review panel evaluated all aspects of the project, including optical design, telescope structure, control systems, science instrumentation, site testing, and management and cost-estimation procedures. The panel praised in particular the adaptive optics technology that will allow the TMT to reach the "diffraction limit," seeing things the way a telescope in outer space would see them. Much of the TMT's scientific work will be done in the infrared, where the diffraction limit is easier to attain, young stars and galaxies are to be found, and the opportunities for new discoveries are abundant.

TMT's eight scientific instruments, also in the detailed design phase, are huge in comparison to current astronomical instruments, and equivalently more complex. Each one is the size of school bus or larger, and they rest on two basketball-court- sized platforms on either side of the telescope. The biggest technical challenges are posed by the Planetary Formation Instrument, which employs "extreme" adaptive optics in an effort to see other planets directly, rather than infer their presence by their effects on their stars, as is currently done.

Says Richard Ellis, Caltech's Steele Family Professor of Astronomy, "We'll decide in mid-2008 where to build the telescope and then start construction in early 2009."

Science operations are slated to begin in 2016. The TMT project is studying five sites in Chile, Hawaii and Mexico, and the project's offices are located at CIT^2, formerly St. Luke's Hospital, in Pasadena, where the design review was held.

The TMT is a collaboration between Caltech, the University of California, the Association of Universities for Research in Astronomy, Inc. (AURA), and the Association of Canadian Universities for Research in Astronomy (ACURA), with significant instrument-design work being done by industry and by university teams. TMT's design and development phase has a budget of $64 million, including $35 million in private-sector contributions from the Gordon and Betty Moore Foundation. □—*RT*

On the road again: The Fleming cannon journeys cross-country from Caltech to That Other Institute of Technology and back again in this commemorative pen, available for $3.95 at the Bookstore. Visit www.bookstore.caltech.edu if you can't stop by in person. And while you're there, pick up the MIT "because not everybody can go to Caltech" T-shirt that started it all.

LEGOs for Biochemists

Figuring out how proteins fold—that is, the way that amino acid sequences determine the unique structures and functions of protein molecules, which then act as "biology's workhorses"—remains one of the biggest open questions in biology today. One common approach analyzes numerous proteins with similar structure and function—a protein family—to try to tease out the fundamental interactions responsible for a given property. Now a Caltech team of chemical engineers, chemists, and biochemists has created a huge family of proteins that, even though they have very different sequences, all fold the same way.

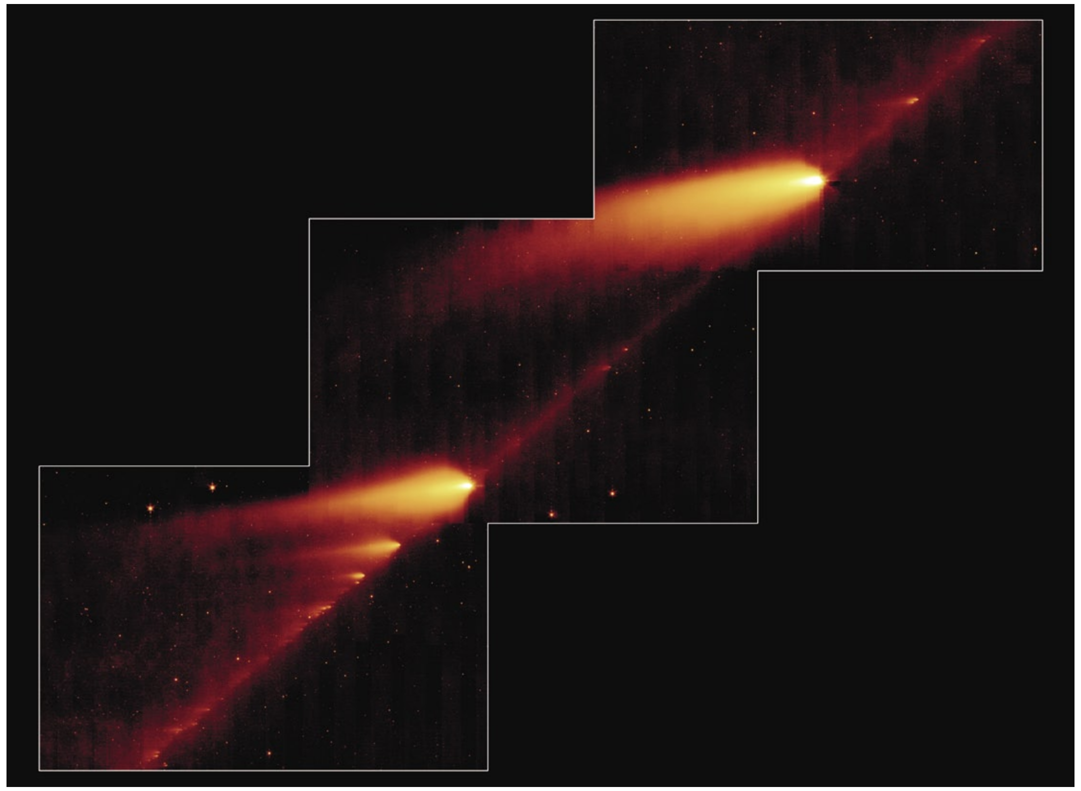
Grad student Christopher Otey and his colleagues used computational tools to analyze three natural protein structures and pinpoint locations at which they could be broken apart and reassembled, like LEGO pieces. The proteins were then broken into eight pieces each and reassembled into all possible eight-piece combinations, creating 3^8, or 6,561, sequences. Only about half of these constructs were able to fold themselves, but those that do constitute "an artificial protein family," Otey explains. "In this single experiment, we've been able to make about 3,000 new proteins."

The viable proteins have an average of about 72 sequence changes. "We can use the new proteins and new sequence information to learn about the original proteins," Otey adds. "For example, you can see if a certain protein function depends on one amino acid that never changes."

The original proteins belong to a family called the P450 cytochromes, which play critical roles in drug metabolism, hormone synthesis, and the biodegradation of many chemicals. The researchers broke these roughly 460-amino-acid proteins into LEGO blocks of about 60 to 70 amino acids each. Over the past 40 years, researchers have fully determined 4,500 natural P450 sequences, but the Caltech team required only a few months to create the new sequences.

"During evolution, nature conserves protein structure, which we do with the computational tools, while changing protein sequence, which can lead to proteins with new functions," Otey says. "Our goal is to be able to create a bunch of new proteins very quickly, but the eventual benefit of understanding what makes a protein do what it does will be in the production of new pharmaceuticals, new antibiotics, and such."

The paper appeared in the April 10 issue of the *Public Library of Science Biology*. The other authors include Frances Arnold, Caltech's Dickinson Professor of Chemical Engineering and Biochemistry; biochemistry postdoc Marco Landwehr; Jeffrey Endelman, PhD '05 in bioengineering; chemistry grad student Jesse Bloom; and postdoc Kaori Hiraga, now at the New York State Department of Health. □—*RT*



Above: Comet 73P/Schwassmann-Wachmann 3 began crumbling two orbits ago, back in 1995. Astronomers speculate that its icy outer crust cracked from thermal stresses upon close approach to the sun, allowing fresh ice in the interior to evaporate, and the pressure from the resulting vapor essentially blew the comet apart. On May 12–28, the comet's 5.4-year orbit brought it some 9,000,000 kilometers from Earth, or about 22 times farther away than the moon, and every telescope on the planet (and aloft!) seems to have been trained on it. This infrared view, from the Spitzer Space Telescope, shows at least 36 identifiable fragments following a trail of millimeter-sized comet-dust particles laid down in previous orbits. Caltech and JPL run the Spitzer for NASA.

NEEDS TITLE

Caltech and BP, the energy company formerly known as British Petroleum, are embarking on an effort to develop cheap, high-efficiency solar cells that will make widespread production of electricity from sunlight a more cost-competitive option. The five-year program will explore ways of growing silicon nanorod arrays, rather than making solar cells by casting silicon ingots and cutting them into wafers, as is conventionally done. The tightly packed nanorods, small cylinders of silicon some 100 times smaller than a human hair, would be arrayed like bristles in a brush.

A solar cell made up of nanorod arrays would efficiently absorb sunlight along its entire length, offering far more collecting area than a flat, wafer-based cell of equal size. The nanoarray would also collect the electricity more efficiently than a conventional solar cell.

The program will be directed by Nate Lewis (BS '77, MS '77), Argyros Professor and professor of chemistry, and Harry Atwater, Hughes Professor and professor of applied physics and materials science. Lewis, an expert in surface chemistry and photochemistry, will use nanotechnology to create designer solar-cell materials, from nanorods to nanowires, and explore their properties to find the optimum ones. Atwater, an expert in electronic and optoelectronic materials and devices, will investigate ways of making the resulting materials and designs using vapor-deposition methods that are scalable to very large areas. "Using nanorods as the active elements opens up radically new approaches to design and low-cost fabrication of high-performance solar cells," says Atwater. Eight grad students and postdocs in Lewis's and Atwater's labs will be funded by the project.

The research contract is part of BP's long-term technology strategy, and partners Caltech with BP Alternative Energy, which was launched in November 2005 to develop low-carbon-emission options for the power industry. Says BP Solar's CEO and president, Lee Edwards, "This program represents a significant commitment by BP to the long-term potential of solar energy. Nanorod technology offers enormous promise. However, like any new technology, challenges remain to be solved to make it commercially viable at scale." □—*RT*

Opposite: The Seismo Lab's remodeled Earthquake Media Center opened for business on June 29. Gone is the wall of drums, a staple of TV coverage but state-of-the art 1950s technology. In their place is a nine-panel, 10-by-6-foot video wall that can display any number of simultaneous images, including "ShakeMovies"—2-D animations of seismic waves superimposed on topographic maps—shaking and felt-intensity maps, and the zigzaggy seismic waveforms that the drums used to produce. The Dell Corporation provided the technology behind the wall.

NOTE: Actual caption may vary somewhat, depending on the picture.

E&S BRINGS HOME THE HARDWARE

For the second consecutive year, *E&S* has won a silver medal in the Research Magazine category in CASE's annual Circle of Excellence competition. CASE, the Council for Advancement and Support of Education, is the world's largest nonprofit education association in terms of institutional membership, including as it does more than 3,200 colleges, universities, and independent elementary and secondary schools in 55 countries around the world. The Circle of Excellence judges some 40 categories of alumni relations, institute advancement, public and media relations, and student recruitment pieces in print and electronic forms. Not all medals are awarded in all categories—in fact, last year no research-magazine gold was given out, and *E&S* shared the silver with the Woods Hole Oceanographic Institution's *Oceanus*. (This year, the University of North Carolina at Chapel Hill's *Endeavors* took the gold.)

Averse as we are to tooting our own horn, we'd like to share some of the judges' comments from 2005 with you. "The best entrants, not surprisingly, keep their readers in the middle of their radar screens. They know their audiences, and they are slaves to them alone. They feature thoughtful writing, inventive story ideas, and display copy that works. . . . *Engineering and Science* . . . excels at meeting its mission and serving its unique readership. . . . Their entry succeeds in meeting its stated goals with a compelling lineup of stories with depth. (Such depth was a critical distinction between both of these publications and all the rest.) The stories and writing were very good, . . . [the] topics were compelling and well executed." The comments from this year's competition will be posted "starting in late September." □—*DS*