Niwa, of Hitachi Ltd.'s Advanced Research Laboratory here, showed an interactive search scheme, called Dual-Navi, that presents search results both concretely and abstractly in side-by-side windows.

Starting with a search string, Dual-Navi presents the typical list of retrieved titles on the left side of the screen while a graph of key words extracted from those retrieved documents appears on the right side. The key words are displayed according to their frequency of occurrence, and associated words are joined by solid lines.

Although the popular AltaVista search engine uses a similar graph, Dual-Navi provides interactive links between the two views. To narrow the search, users select additional key words in the graph view and click a button. The documents containing those words will come to the top of the title list. Conversely, click on a title, and the key words found in that document are highlighted in the graph. Additional titles with similar characteristics can then be gathered. These processes can be repeated, with the graph and list views constantly changing to reflect the latest stage of the search.

Even more user-friendly, however, would be a system tailored to a person's needs. Stanley Peters, a mathematical linguist at Stanford's Center for the Study of Language and Information, presented one approach based on concepts, or groups of synonymous words, extracted from a person's e-mail. The idea, says Peters, is to exploit the "idiosyncratic associations" among words to come up with customized searches.

In one test, researchers generated associations based on 3 months of an individual's e-mail and, for comparison, a database of 42,000 Associated Press (AP) news wire articles. They then searched a target database using four key words—race, identity, Asian, and dating. The results were strikingly different. The documents retrieved using the associations generated from the AP articles were primarily about black-white race relations, while those retrieved using the associations gleaned from the individual's e-mail were much more closely related to issues involving Asian race relations, the individual's primary research interest.

Peters believes this approach could be extended. Civil engineers and stamp collectors, for example, could use sets of associations generated from databases of civil engineering journals or philatelic magazines to narrow the range of retrieved documents when searching something like the Web. But even this feature has its limitations. "There is not likely to be one approach that suits all particular needs," Peters says. So, while trolling through the ocean of information may get easier, it is still going to take work to stay afloat.

–**Dennis Normile**

MICROBIOLOGY

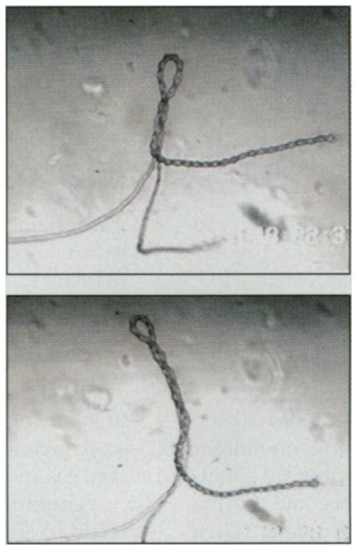
Physics, Biology Meet in Self-Assembling Bacterial Fibers

Twenty years ago, when Neil Mendelson first described a mutant strain of bacteria that twisted itself into ropy helical fibers, his fellow microbiologists considered it just a curiosity, one of many in the world of microbes. As Mendelson, a professor at the University of Arizona, narrowed his research to focus on the quirky twists and turns of these bacteria, the scores awarded to his grant applications took a nose dive and so did the number of papers he published in peer-reviewed microbiology journals.

Lately, however, Mendelson's odd microbes have been making a name for themselves in some unexpected settings, far from microbiology. They have won devotees among mathematicians, engineers, and physicists who, collaborating with Mendelson, have used the microbial fibers to help solve long-standing problems in elasticity theory, model solar flares, and make a new siliceous material that could be used in medical implants. Mendelson was "a pioneer and out of the mainstream," says Ralph Slepecky, a professor emeritus of microbiology at Syracuse University in New York. "But his work is proving useful."

What has sparked all this interdisciplinary effort is a mutant form of a common, rod-shaped bacterium called *Bacillus subtilis*, about 4 micrometers long and 0.7 micrometer in diameter. Back in 1975, Mendelson discovered a strain lacking the enzymes that normally cleave daughter cells after cell division, so that the daughters grow stuck to their parent cells like beads. Individual filaments of linked bacteria spontaneously twist and double back on themselves many times to form a thick, rope-like helical coil of up to 100 filaments (*Science*, 3 January 1992, p. 32). Mendelson dubbed these coils "macrofibers," and while their unique penchant for self-assembly may have left some microbiologists cold, it piqued the interest of physical scientists.

For example, when Michael Tabor, head of applied mathematics at the University of Arizona, first saw a film of macrofibers self-assembling in 1992, he realized that he had found a living, dynamic model for flexible elastic filaments. Mathematicians have been modeling the way these filaments twist for more than a century, but most models were static—describing only starting and ending structures, rather than the complex stages in between, says Tabor. His group, including postdoc Alain Goriely, spent several years observing *B. subtilis*—live and on video—and developed new dynamic equations to describe the twisting and coiling of macrofibers. Their analysis describes a seemingly unpredictable aspect of macrofiber coiling: how two-dimensional twisting causes the fibers to kink or rise up from a flat surface, adding a third dimension to their shape. For many natural systems, the spontaneous twisting of the bacterium is a better model than, say, a rubber band, which twists only in response to an outside force, says Tabor.

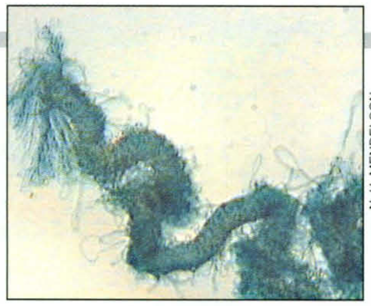


N. H. MENDELSON

Self-starters. Bacterial filaments *(top)* twist spontaneously into helical fibers *(above)*.

Mathematicians call this move into a third dimension "writhe." Tabor's model shows that writhe stems from subtle mathematical instabilities: When the researchers altered certain variables in their equations, the solutions required a shift into three dimensions. These mathematical instabilities are likely to be a general property of elastic filaments, Tabor says, although he doesn't know to what physical properties they might correspond. Because elasticity theory is used to model everything from the supercoiling of DNA to the twisting of magnetic field lines in a star, the new model will likely have plenty of applications, adds Mendelson's collaborator John Thwaites, a mechanical engineer at Cambridge University.

In fact, Tabor's model of elastic filaments has already been applied to the behavior of so-called magnetic flux tubes in the sun. These structures, made up of bundles of magnetic field lines, cause sunspots and can trigger the enormous magnetic detonations on the surface of the sun known as solar flares. The tubes emerge from the sun's interior as narrow strands of magnetic field, which float to the surface and appear as sunspots. The long tails trailing back into the interior can be modeled as elastic filaments, because ionized gases associated with them have mass and anchor the magnetic flux tubes in the interior. Because one end is weighted down, the filaments acquire tension, explains physicist Dana Longcope of Montana State University (MSU) in Bozeman.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Biofiber. A bacterial "macrofiber" expresses a reporter gene (blue).

But theorists have had a hard time explaining how this tension causes flux tubes to twist above the surface of the sun and trigger flares, says Longcope. Then, MSU mathematician Isaac Klapper, who worked with Tabor, showed Longcope the new elasticity model for supercoiling bacteria. "I knew these were the equations that could describe magnetic flux tubes," says Longcope, and "it was a surprise that they came from bacteria." When applied to the sun, the model showed that the twisted magnetic flux tubes release their stored-up energy by writhing out of their plane, thus triggering solar flares. Longcope and Klapper describe this in a paper in press at the *Astrophysical Journal*. Modeling solar flux tubes is the first step in understanding them, and perhaps eventually predicting the flares, which emit energetic particles that can damage satellites, says Klapper.

Meanwhile, materials scientists have been pursuing another line of research on mutant *B. subtilis*. When cultured in crowded conditions, the separate strands become matted together into webs resembling spaghetti in a bowl. Mendelson invented a device to pull meter-long threads from webs; a thread contains up to 30,000 parallel bacterial filaments and "looks like nylon fishing line," says materials chemist Stephen Mann of the University of Bath in England.

Mendelson found that because the cell walls of *B. subtilis* consist of two negatively charged polymers that attract positively charged minerals, the threads bind mineral salts in solution, including those of iron, calcium, and copper. These encase and stiffen the threads, forming a crystalline fibrous framework—and opening a whole realm of potential new materials. Called bionites, these bacterial-mineral hybrids look like red, black, green, or silver fiberglass, depending on the mineral used. Weight for weight, bionites are stronger than steel, yet are also biodegradable.

In the most recent bionite work, Mann, Mendelson, and colleagues created siliceous bionites that may be useful for medical implants. Ordinary silica is a good candidate for implants because it is fairly inert and doesn't react with tissue. But an ideal material would be porous, so that natural tissue could attach to it, explains Stuart Williams, chair of biomedical engineering at the University of Arizona. Silica naturally contains only nanometer-sized pores, too small for cells to gain a foothold, he says.

Bionite researchers were able to improve on nature. Mann's team first made siliceous bionites, then burned out the bacterial fibers by heating them in an oven. The resulting white silica fibers contained ordered channels of two sizes: the tiny, natural pores, as well as larger channels 0.5 micrometer wide left by the fibers (*Nature*, 30 January). These large channels could provide a scaffolding for cell growth, as well as a route for antibiotics or growth factors added to the implant to leak slowly into surrounding tissue, says Williams, who calls this "a major improvement" in medical materials.

Even in microbiology, the mutant *B. subtilis* is finally getting its due. The microbe's antics are making their way into microbiology texts and for the first time in 20 years, Mendelson spoke by invitation at last year's annual meeting of the American Society for Microbiology. Accepting his ideas took time because of his "unique approach" and focus on mechanics, says microbiologist Gerald Shockman of Temple University in Philadelphia. But whether the research is called microbiology, mathematics, or materials science, it's clear that Mendelson's microbes have come into their own.

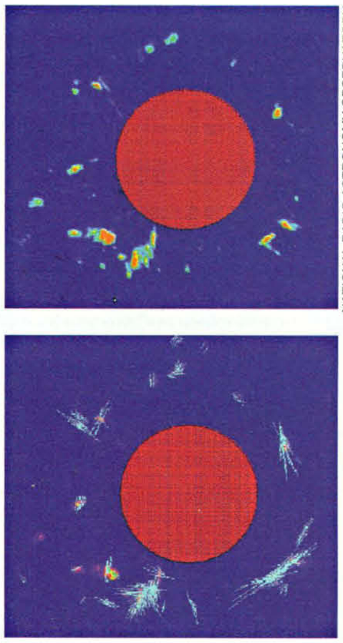
–Carol Potera

Carol Potera is a science writer in Great Falls, Montana.

ASTRONOMY

Mapping a Star's Magnetic Field

Astronomers have enlisted a continent-wide array of radio telescopes to map the magnetic field of a bloated red giant star. This first magnetic map of another star, to be published this week in *Astrophysical Journal Letters*, suggests that at least some stars have magnetic fields resembling those of Earth and the sun. And the details of the map—about 50 times smaller than the finest features visible to the Hubble Space Telescope—could help theorists model how red giant stars shed gas and dust into interstellar space.


NATIONAL RADIO ASTRONOMY OBSERVATORY

Fine detail. Regions of intensified radio emission around a red giant star *(top)* enabled astronomers to map parts of its magnetic field.

Astronomers can't observe magnetic fields directly, so Athol Kemball and Philip Diamond of the National Radio Astronomy Observatory in Socorro, New Mexico, relied on radio waves, which are polarized by magnetic fields. Normally, the radio waves from the star they observed—TX Camelopardalis (TX Cam), which lies about 1000 light-years away—would be too faint to see. But TX Cam is swathed in clouds of excited silicon monoxide molecules. These clouds act as an amplifying medium for radio waves, in much the same way that a laser amplifies light.

To pick up the signals and map their polarization, Kemball and Diamond turned to the Very Long Baseline Array (VLBA), a network of 10 identical radio telescopes that stretches across the United States. By combining signals from its far-flung dishes, the VLBA mimics a single antenna the size of the continent, picking up details that would elude smaller telescopes.

The VLBA's map of radio polarization across TX Cam is "strongly suggestive of order in the magnetic field," says Kemball, although he cautions that the map shows only two dimensions and doesn't pin down the field's north and south poles. But Kemball says the field's most likely structure is similar to Earth's field, with magnetic field lines looping around the planet parallel to lines of longitude. In several spots, however, the field lines are twisted and kinked, much as they are around flares on the sun. The magnetic kinks could affect the way gas and dust escape from the star, says Kemball.

He and Diamond hope to monitor TX Cam every 2 weeks, looking for changes in the field lines to see whether this giant star has a magnetic cycle. Meanwhile, astrophysicists are delighted by their first clear pictures of a star's field. The resolution, says Mark Reid of the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, "is truly astounding."

–Erik Stokstad