asthenosphere. When researchers plugged in a viscosity that Romanowicz calls "reasonable but a bit on the low side" of current estimates, the crest of the stress wave entered the eastern Arctic Ocean in the 1970s; it passed off British Columbia around 1975, and California around 1985. Wherever the wave passed, it briefly accelerated plate motions, which could have spurred earthquake activity.

The timing is a good fit to surges of seismic activity, say Pollitz and his colleagues. According to the model, the wave may have triggered the surge of magnitude 5 and greater quakes observed in the eastern Arctic Basin in the 1980s. To the south, the wave's progress—marked by accelerations of only a couple of millimeters per year—could be seen in pulses of increased seismicity in Northern California in the 1970s and Southern California in the 1980s.

Even the types of earthquakes seemed to fit stress-wave triggering, says the group. The Southern California seismicity mostly took the form of quakes on faults other than the San Andreas. The sides of these faults move chiefly up and down rather than sideways, as the San Andreas does. That feature of the seismicity was noted in 1995 by seismologists Frank Press of the Washington Advisory Group in Washington, D.C., and Clarence Allen of the California Institute of Technology in Pasadena, who speculated that a stress wave oriented to favor vertical fault motions might be responsible. The wave set off by the great Alaskan quakes fits the bill, Pollitz's team says. "The whole thing seems to hang together," says Press.

But others point out that the correlation of the passing wave with a flurry of seismicity could be chance. "There have been many interesting patterns in seismology that have turned out to be wonderful coincidences," says seismologist Lucile Jones of the USGS in Pasadena. And the stress wave, dampened by distance, seems too weak to trigger quakes, other researchers say. The extra strain added by the wave would be "really small," says Thatcher, perhaps a factor of 10 smaller than what's assumed to trigger quakes at short range.

"Yes, the strain changes are small," concedes Romanowicz, "but I don't think anyone has a definite idea of how much strain you need to trigger an earthquake." Bürgmann adds that a coincidence is unlikely, because seismicity along the entire west coast fits the stress-wave theory.

Further tests of this bold idea are in the works. Although existing geodetic networks weren't sensitive enough to catch the subtle stress changes signaling the arrival of the wave, says Bürgmann, current systems should record its departure in the coming decade. Then it should become clear whether distant earthquakes are the interfering busybodies he and his colleagues suspect they are.

–Richard A. Kerr

ECOLOGY

Ecosystem 'Engineers' Shape Habitats for Other Species

In Israel's Negev desert, some microbes have developed a unique survival strategy: They pave the desert. Several species of bacteria and cyanobacteria secrete long-chain sugars that bind soil and sand into a black crust, which protects their damp colonies from the searing heat. But the microbes' labor benefits other species as well, according to Moshe Shachak and Bertrand Boeken of Ben-Gurion University in Sede Boker, Israel. After a downpour, the asphaltlike patches reduce water absorption by about 30%, increasing runoff, which pools in pits dug by desert porcupines and beetles. Windblown seeds germinate in the moist pits, giving rise to lush oases that can harbor dozens of species. "We see enormous effects … by a host of tiny organisms," says Shachak.

MICHAEL DICK / ANIMALS ANIMALS

Engineer at ease. The desert porcupine digs holes in the sand that give rise to miniature oases, which attract other species.

"Ecosystem engineers" like these microbes have sparked a new approach to assessing how species interact with one another. Shachak, together with ecologist Clive Jones of the Institute of Ecosystem Studies in Millbrook, New York, and John Lawton of Imperial College's Centre for Population Biology in Silwood Park, U.K., have proposed a new concept of how ecosystem engineers, by shaping habitats to their own needs, alter the availability of energy—food, water, or sunlight—and thus dictate the fates of other species.

The concept has generated quite a stir among environmental scientists since it appeared in the journal *Ecology* last October. "Nobody had stepped back before and asked if this was a general phenomenon, then tried to put down some guiding principles," says David Tilman, an ecologist at the University of Minnesota, St. Paul. "This is one of those rare papers that gets you thinking in a new way." He and others think that after fine-tuning, the concept of ecosystem engineers may be ready to join an elite set of theories, such as natural selection and predator-prey theory, that help explain how species arise and interact.

Missing from ecology's theoretical underpinnings has been a way to account for how species, by altering habitats, perturb other species—even though, as Jones explains, "we've known for a long time that there are things species do to their physical environment that have enormous knock-on effects throughout the ecosystem." Then a few years ago, he and Lawton heard about the Negev story. The scientists soon grasped that ecosystem engineering was far more pervasive than humans erecting skyscrapers or beavers building dams. "Once we started looking in the literature and talking to people about this," says Jones, he and his colleagues realized "how important ecosystem engineers are at affecting species diversity, distribution, and survival."

The concept's guiding principle is that engineers indirectly control the flow of energy within an ecosystem. These species, the ecologists say, can have just as great an influence on an ecosystem as keystone species, or top predators. The concept holds that ecosystem engineers alter habitats through two overarching mechanisms. Autogenic engineers transform ecosystems by their own growth and are integral to the altered environment. Corals, for example, build reefs for their own needs that also serve countless other species. Although some species feed on coral, most, including brittle stars, anemones, and sponges, use reefs only for shelter. Similarly, trees create habitat for myriad species that live in and among tree crotches, where large branches diverge from trunks. Without coral reefs or trees, says Jones, associated species would perish.

The second class of organisms, allogenic engineers, alter the environment and then move on, leaving structures behind. Beavers, for instance, turn stream ecosystems into pond ecosystems by building dams that block stream flow. The pooling water drowns grasses and shrubs but provides marsh for herons and other species; crustaceans colonize debris from beaver dams. The Negev bacteria are also allogenic engineers.

The ecologists list six factors—including population density of an engineering species and the types of resources it controls—to help assess an engineer's importance to an ecosystem. The researchers hope that this framework can be used to make predictions about how, for instance, engineers that invade an ecosystem might alter it.

Researchers are already putting the concept to the test. Entomologist Bob Marquis and grad student John Lill of the University of Missouri, St. Louis, are studying how *Pseudotelphusa* caterpillars tie oak leaves together to form shelters. They have found that dozens of species—including spiders, weevils, and aphids—dwell in the shelters. By forcing researchers to look for those species that indirectly alter energy availability, the engineer concept "could help organize a great deal of what we're seeing in our experimental systems," says Marquis. Indeed, he says, it has prompted him and Lill to revise their research plan. Instead of merely observing engineers in action, says Marquis, "we are going to manipulate the leaves ourselves to quantify the effects of the leaf ties on the resulting ecosystems."

Others hope to put the concept to predictive use. Lawton and mathematician William Gurney of the University of Strathclyde in Glasgow, U.K., are trying to devise robust computer models that forecast how an engineer's activities could affect other species. "Experiments are now getting started," says Lawton, "but it will probably be a decade before we can really say what shape the models, and ultimately the theory, will take." Such models could someday be useful for protecting or restoring habitats. "It's hard to think about conserving ecosystems without considering the effects that engineers have on a system," says Shachak.

Experts agree that the nascent concept needs sharpening to help researchers home in on the engineers that, like keystone species, are crucial to an ecosystem's overall health. "At some level you could say that every organism is engineering its ecosystem and that this activity affects other organisms," says Alex Flecker, an ecologist at Cornell University in Ithaca, New York, who studies the ecosystem effects of fish that bulldoze sediments to find food in Andean streams. But "the important thing," Flecker says, is that the new concept has "organized the different types of engineering behavior we see in the field into a useful, testable framework."

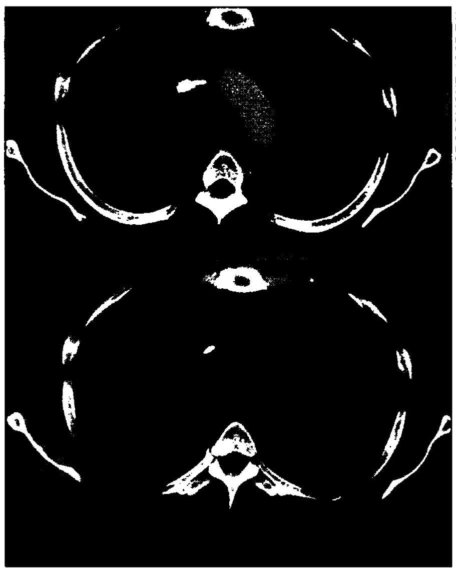
–Joseph Alper

Joseph Alper is a free-lance writer in Louisville, Colorado.

CANCER THERAPY

Antibodies Stage a Comeback In Cancer Treatment

As investors in new cancer therapies ought to know, the history of cancer research is rife with reports of cancer "cures" that all too often turn out to be ephemeral. In 1982, for example, immunologist Ron Levy of Stanford Medical Center raised the hopes of many when he reported in *The New England Journal of Medicine* that he had vanquished cancer in a patient, Philip Karr, using antibodies custom-designed to attack Karr's own lymphoma cells. In the wake of the resulting optimism, Levy co-founded IDEC Pharmaceuticals to commercialize his discovery, and other white-hot biotech companies pounced on the idea too. Expectations—and stock values—soared. "It was assumed [that antibodies] would be the final answer, that we could just produce them and the rest of cancer research could close up shop," recalls radiation oncologist Alan Lichter of the University of Michigan Medical School in Ann Arbor, who is president of the American Society of Clinical Oncology (ASCO).



GROSSMONT HOSPITAL

Antibodies attack. After treatment with IDEC's antilymphoma antibody, this patient's tumor near the heart *(top)* vanished *(above)*.

Then, in an object lesson in the dangers of hyping cancer therapies, hopes—and stock values—shriveled. Although Levy's antibody worked, the effects of other antibodies in humans didn't match those in mice, and unexpected toxicity even killed patients, bringing clinical trials to an abrupt halt. Antibodies vanished from page one, and many firms abandoned them.

But now, after a decade and a half of hard work, the tide may be turning again. Last fall, IDEC of San Diego finally received approval from the U.S. Food and Drug Administration (FDA) for an antilymphoma antibody, a cousin to Levy's original preparation. Just last week, researchers announced some success with an antibody tailored to fight recalcitrant breast cancers that is nearing regulatory approval. A handful of antibodies are in earlier stage clinical trials, with a smattering of positive results. And dozens more are in preclinical testing around the world. "We're entering a period of cautious optimism," says tumor immunologist Lloyd Old, director of the Ludwig Institute for Cancer Research in New York and co-organizer of an antibody meeting held in Manhattan last month.* Akhtar Samad, an analyst with the New York–based Mehta Partners, agrees: "We're in the early stages of renewed investor interest and confidence."

Researchers caution, though, that antibodies aren't the "magic bullets" hyped in the past, nor will they ever replace conventional cancer chemotherapy drugs. Indeed, so far results show that they may work best when combined with those drugs. "Typically in cancer treatment, you're looking at multiagent, multimodality therapy," says clinical oncologist Antonio Grillo-Lopez of IDEC.

The theory behind antibody therapy is straightforward. Antibodies are a first line of the body's defenses against infection. Each antibody grasps a specific target, or antigen, and holds on, meanwhile alerting the rest of the immune system to the intruder. Make antibodies that target antigens produced by tumors and inject them into the bloodstream, the theory went, and they would converge on a tumor and destroy it.

Some antibodies lived up to that promise—and continue to do so. For example, in the longest running clinical trial of a therapeutic cancer antibody, immunologist Gert Riethmüller of the University of Munich in Germany and colleagues report success in preventing colon cancer from spreading by giving, after surgery, a mouse antibody called Panorex, which targets a protein found in both normal and cancerous gut cells; this protein helps cells stick together and, in the case of cancerous cells, may help metastases to form. After 7 years

* Antibodies 1998, the Cancer Research Institute, New York, April 22–24.