AAAS MEETING
GENETICS

Becoming a Symbiont Is in the Genes

Some couples enjoy a harmonious intimacy that many people can only dream of. Such is the alliance between certain bacteria and plants, in which each partner provides an essential gift, with the microbes nestled comfortably within the plant. At the meeting, molecular biologist Sharon Long of Stanford University described several new genes that may play key roles in a bacterium's transition from independence to symbiosis. Although the lessons offered by these cross-kingdom pairs are unlikely to enhance human relationships, they may someday open the door to improved crop production.

AAAS MEETING

This collection of stories captures the breadth of science, from new genes involved in symbiosis to insights into monogamy, featured at the American Association for the Advancement of Science Annual Meeting in Anaheim, California, 21 to 26 January.

After infecting legumes, *Rhizobia* fix nitrogen by grabbing the gas from pockets of air in the soil and converting it into ammonia, which the hosts use to make protein. In return, the plant provides the bacteria with nutrients and private quarters in root nodules. Researchers know how legumes and *Rhizobia* first catch each other's attention, but the pas de deux after the sparks fly and before the microbes have settled into their new home remains largely a mystery. Long's team is catching the first glimpses of this courtship's middle stages. "We're looking at a step that's largely unknown, and we may uncover unanticipated things that will help us understand what makes symbiosis succeed or fail," she says.

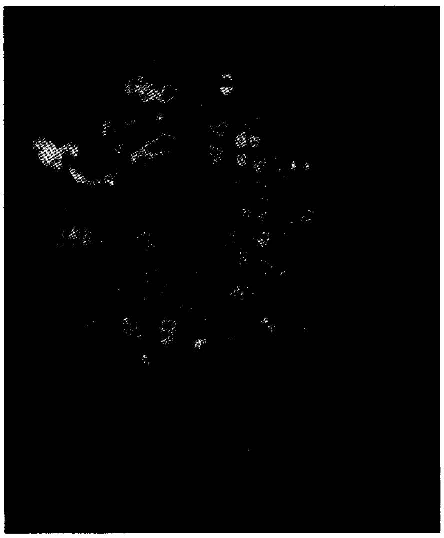
To figure out what molecules are involved, Valerie Oke, a postdoctoral fellow in Long's lab, set out to look for bacterial genes that turn on at some time in the interval after a bacterium latches onto the tip of a root hair and before it starts fixing nitrogen. Already, Oke has uncovered several surprises. One gene encodes a protein that resembles fasciclin I, which in insects glues nerve cells together and guides them during embryonic growth. The researchers don't know how the bacteria use this protein, but they have shown that plants infected with rhizobial strains lacking the gene fix nitrogen inefficiently. Further evidence that the gene plays a role in symbiosis comes from Daniel Gage, a microbiologist now at the University of Connecticut, Storrs, who independently isolated it when he was a postdoc in the Long lab during a search for proteins that *Rhizobia* secrete when infecting host plants.

Another of the genes Oke identified appears to produce a protein similar to ones that disarm destructive oxygen molecules in a variety of organisms. This suggests that the bacteria encounter such harmful molecules after infecting the plant, says Long, which hints that the legumes might at first consider *Rhizobia* enemies. The presence of the gene, she says, raises questions about where to draw the line between pathogen and symbiont. On the other hand, she says it's equally plausible that the plants are not mounting a defensive response, and that the gene's presence may simply reveal "something basic about plant physiology."

"I'm very impressed and excited by this new work," says R. James Cook, a plant pathologist at Washington State University in Pullman. Exposing the intimate details of the plant-bacteria relationship could help researchers such as Cook find ways to improve the efficiency of nitrogen-fixing bacteria and even transfer some of their abilities to other species. For instance, strains of *Pseudomonas* and *Bacillus* make antibiotics that help protect plants from root infections, but these bacteria live "casually" in the vicinity of the plants, says Cook, and thus are at the mercy of fluctuations in soil conditions and other environmental whims. *Rhizobia*, meanwhile, have a safe haven. "I don't know if these genes are what we're waiting for," he says, "but it would be exciting to find out if they can enhance the ability of these antibiotic-producing bacteria to associate with roots."

In another fantasy, scientists would figure out how to introduce nitrogen-fixing bacteria into crops that aren't cozy with helpful microbes, such as wheat and corn. This arrangement could make it possible to grow those plants in nitrogen-poor soil without fertilizer—a boon to farmers. Such a project would require more detailed information about the genetic contributions to the symbiotic relationship from both plants and bacteria. Long says she's pessimistic that the endeavor will succeed anytime soon, but "we're gathering the tools to test the idea. I wouldn't have said that 2 years ago." Even if scientists can't figure out how to spark romance between every crop and nitrogen-fixing bacterium, they seem to be well on their way to figuring out what makes certain plant-microbe pairs click.

–EVELYN STRAUSS



Warpath. Gene finds shed light on how nitrogen-fixing bacteria (whitish blue) invade a root nodule (green-orange).

CREDIT: MARK DUDLEY AND SHARON LONG

AAAS MEETING
LINGUISTICS

Grammar's Secret Skeleton

It's been more than 3 decades since scientist-dissident Noam Chomsky hit his colleagues with a controversial theory: that babies learn how to speak so easily because they're born with a sense of grammar that transcends individual languages. Chomsky, a linguist at the Massachusetts Institute of Technology (MIT), challenged researchers to find simple rules that govern all languages, from Arabic to Zulu. Now some linguists claim to have at last uncovered key elements of this universal grammar—and their findings, presented at the meeting, are rekindling a debate over whether grammar is innate.

Guglielmo Cinque got the fireworks started at a packed symposium with his description of common grammar elements spanning dozens of cultures. Cinque, a linguist at the University of Venice in Italy, recalls being struck several years ago by how certain adverbs—"always" and "completely," for example—appear in the same order in a sentence in languages as disparate as Italian, Bosnian, and Chinese. Looking more closely, Cinque realized the same was true for auxiliary verbs, particles, and other parts of speech.

He and his students then set out on a linguistic odyssey, surveying word order and meaning in some 500 languages and dialects. After more than 4 years of sifting through grammatical analyses and querying native speakers, the researchers found that every language consists of sentences based on a verb phrase surrounded by modifiers in predictable patterns. Because this core structure does not vary, Cinque concludes that "our human species imposes these rules on language as part of our genetic endowment." Cinque, who lays out his argument in a new book, *Adverbs and Functional Heads: A Cross-Linguistic Approach* (Oxford University

Press, 1999), adds: "It's an accident of birth, like having five fingers instead of seven."

More focused comparisons have yielded similarly provocative conclusions. In another talk, MIT linguist David Pesetsky, a former student of Chomsky's, examined the Question Rule, or the arrangement of parts of speech in a question. At first glance, questions appear strikingly different in many languages. In English, for example, we ask, "Whose book did Mary buy?" In Russian, the same question, "Chju Marija kupila knigu?" (translated word for word), comes out as "Whose Mary bought book?" Comparing these sentences and equivalents in Bulgarian and Okinawan, a Japanese dialect, Pesetsky and students Paul Hagstrom and Norvin Richards have discovered a recurring syntax theme: No matter what their native tongue, people consistently place variations on the word "whose" and accompanying words at one end of a sentence.

Both sets of findings are compelling, says Victoria Fromkin, a linguist at the University of California, Los Angeles (UCLA). "The universal properties they've found—combined with the fact that children show an amazing ability to pick up language—make a very strong case that our species is biologically endowed with a set of rules for communication," she says. But some researchers contend that Cinque, Pesetsky, and their colleagues are overreaching. "We all agree that humans have a language faculty," says UCLA's Edward Keenan. "What's at issue is how specific it is." But regarding precise rules for a universal grammar, he says, "the evidence just isn't in." Pesetsky demurs: "I think we're tapping something basic here." –KATHRYN S. BROWN

Kathryn S. Brown is a science writer in Columbia, Missouri.

AAAS MEETING
NEUROBIOLOGY

Magnetic Cells: Stuff of Legend?

Many animals are attuned to a world hidden from our perception: Bats bounce sound waves off prey, snakes slither through grasslands awash in infrared light, and sharks hunt in the electrical trails of their next meal. Now scientists have taken a step closer to confirming the existence of another sense: the ability to use Earth's magnetic fields to navigate on starless nights or in turbid waters. Migratory and homing animals such as birds, bees, and fish seem to possess a built-in compass, and at the meeting Carol Diebel of the University of Auckland in New Zealand presented new findings on the iron-laden cells that may provide these creatures with a legend to Earth's magnetic road map.

Two years ago, a team led by Diebel's colleague Michael Walker showed that captive trout could be conditioned to nudge a bar and receive food when the fish detect a magnetic field. In a 1997 report in *Nature*, the group traced this magnetic sense to nerves rooted in tissue, rich in iron crystals, located in the trout's nose. Now Diebel and Walker have found that these crystals—presumably composed of magnetite, a mineral used in the first humanmade compasses—are polarized like a bar magnet, and that they appear to be strung together in chains inside so-called magnetoreceptor cells. Scientists who have been engaged in a decades-long hunt for these cells—and have endured derision for working in a field tarnished by dubious research—say they feel vindicated. "This is the last nail in the argument for these things being the magnetoreceptor cells," says Joseph Kirschvink, a geobiologist at the California Institute of Technology in Pasadena who first proposed the magnetite-based magnetoreception theory 20 years ago.

Over the past 3 decades, magnetite has been found in life-forms as diverse as bacteria, birds, whales, and humans. Although the 50-nanometer particles are just the right size to act as bar magnets in the body (crystals too large would set up interfering fields, while those too small would create unstable fields), locating the magnetite-bearing cells in higher organisms has been like trying to autopsy a living person: The tissue-dissolving methods used to identify magnetite turn the sample to mush.

Diebel knew her team was looking for a needle in a haystack. Organisms contain very little magnetite and the cells that harbor it could be anywhere, as magnetic fields pass through the body relatively unimpeded. "You could spend forever trying to find nanometers of crystal in millimeters of tissue," she says. "We had to invent new methods every step of the way." Her group turned to a magnetic force microscope, running it less than a hair's width above thin slices of trout nose tissue. Positive charges in a magnetic field attract the magnetized probe, and negative charges repel it. The trout snout lit up the computer screen. "We were jumping around the room when we saw this blip" representing a magnetic dipole, Diebel says.

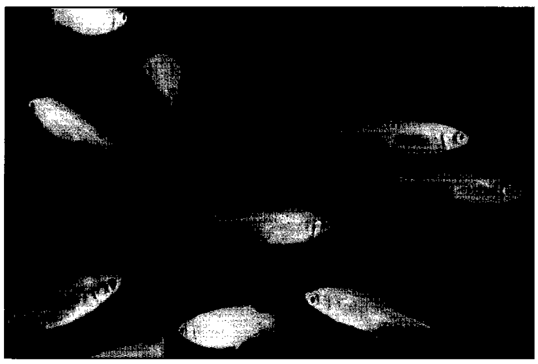
The group next used a confocal microscope to map structures within the putative magnetoreceptor cells, arrayed in the shape of a three-leaf clover. They discerned what appeared to be chains of magnetite that resemble those in bacteria which respond to a magnetic field. How the chains may function in multicellular organisms is anybody's guess, but Kirschvink speculates that changes in Earth's magnetic field twist the chains, perhaps forcing open ion channels that send signals to the brain.

Not everyone is convinced the scientists have uncovered the whole picture. "These cells appear to be involved in magnetoreception, but their role in behavior is still unclear," says John Phillips, a neuroethologist at Indiana University, Bloomington, who studies how light helps newts orient themselves in their surroundings. To tie the mechanism to behavior, researchers still must try to disrupt the cells and show an effect on navigation. The work could open the door to exploring an enduring biological mystery: whether, unwittingly, we use the traces of magnetite in our own bodies to make more sense of this bewildering world. –MELISSA MERTL

AAAS MEETING
BIOENGINEERING

Fishing for Toxic Chemicals

Many toxicologists can remember being dogged at some point by people opposed to chemical tests on animals. But when Richard Winn, a toxicologist at the University of Georgia, Athens, asked one protester how she would feel if lab mice and rats were retired in favor of fish, she answered, he recalls, "that because fish don't have faces, she would be much more comfortable." If other animal activists feel the same way, then Winn has moved a step closer to



CREDIT: R. WINN

Guinea pigs with gills? Medaka fish could supplant rodents as the animal of choice for tox labs.

easing the disapproval that he and his colleagues often feel. At the meeting, he described a promising new line of fish for screening toxic chemicals.

To enhance their ability to detect the mutations that chemicals might cause, in the mid-1980s toxicologists began equipping lab mice with bacterial genes that can be pulled out and screened for damage. This is much easier than, say, screening the