**Gone wild.** Once domesticated, the dingo went feral after reaching Australia.

Wilton, who presented the work. "It may have been one pair or a group of closely related dogs. It may even have been a single pregnant dog."

The new study is "very convincing and thorough," says evolutionary biologist Robert Wayne of the University of California, Los Angeles, an expert on the domestication of the dog. "It really suggests there was a single founding event."

Until now, dingo DNA had not been studied for clues to the dog's origins, and their fossil record is sparse. The earliest documented fossils are a mere 3500 years old, and dingoes never reached the island of Tasmania, which was separated from the mainland by sea level rise 12,000 years ago. Thus experts had concluded that the dog arrived between 3500 and 12,000 years ago, most likely about 5000 years ago—long after dogs were trotting after their humans in most of the rest of the world.

Wilton and his colleagues, including Peter Savolainen of the Royal Institute of Technology in Stockholm and others in Sweden and New Zealand, compared a 582-base-pair stretch of noncoding mitochondrial DNA (mtDNA) in 211 dingoes from across Australia, 676 dogs from around the world, 38 Eurasian wolves, and 19 pre-European dog fossils from Polynesia. They discovered that "all dingoes have a very similar type of DNA," says Wilton. "Any variation is only a single mutation away from the main type." That profound homogeneity shows that the founding population must have been just a few dogs, he says. Assuming a steady mutation rate, the team estimates that all the dingo mutations did indeed arise in the past 5000 years.

Combining these results with previous work, Wilton can sketch dingo history. Last year, in a study on the origin of domestic dogs, Savolainen and colleagues showed that dogs were first domesticated from wolves in East Asia about 15,000 years ago (*Science*, 22 November 2002, p. 1610). In the new study, Wilton found the dingo "main type" in some dogs in East and Southeast Asia, Siberia, Japan, and the Indonesian archipelago. "Have you ever seen a New Guinea Singing Dog? It's a dingo with stumpy legs," jokes Wilton. Thus he suggests that the ancestor of the dingo and its cousins appeared in China 10,000 to 15,000 years ago and was brought south by people, with Indonesia as the last port of call. "Australia was the end of a long chain of migration," he says. Still, he notes that some dingoes must have been taken back to Indonesia in the early days, because some Indonesian dogs have lice and parasites that evolved in kangaroos.

Unfortunately for romantics, the team found that wolves—the original wild dogs—do not carry the dingo main type. That scotches the notion that the dingo too had wild roots. Instead, the wild behavior seen today developed because the original domestic mutts went feral soon after they were brought to Australia, says Wilton.

Dingo lovers may be relieved to know that despite their domestic beginnings, dingoes are still special: They're a unique remnant of an early, undifferentiated dog. "Dogs were just dogs then," says Wilton. "Breeds are a fairly new thing."

But the dingo's unique gene pool may be vanishing, thanks to inbreeding with modern dogs. Already 80% of dingoes along the Australian east coast are hybrids, and no programs are in place to isolate "pure" dingoes in the wild, says Wilton. "It gets worse all the time," he claims. "They may be extinct in 50 years." –LEIGH DAYTON

Leigh Dayton writes from Sydney, Australia.

Molecular Electronics

# Next-Generation Technology Hits an Early Midlife Crisis

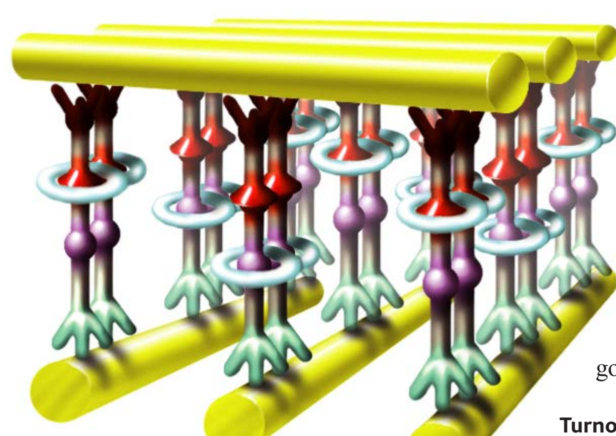
**Researchers had hoped that a new revolution in ultraminiaturized electronic gadgetry lay almost within reach. But now some are saying the future must wait**

Two years ago, the nascent field of molecular electronics was riding high. A handful of research groups had wired molecules to serve as diodes, transistors, and other devices at the heart of computer chips. Some had even linked them together to form rudimentary circuits, earning accolades as *Science*'s 2001 Breakthrough of the Year (*Science*, 21 December 2001, p. 2442). The future was so bright, proponents predicted that molecular electronics–based computer chips vastly superior to current versions would hit store shelves in 2005.

Now, critics say the field is undergoing a much-needed reality check. This summer, two of its most prominent research groups revealed that some of their devices don't work as previously thought and may not even qualify as molecular electronics. And skeptics are questioning whether labs will muster commercial products within the next decade, if at all.

"There are a number of parts of the field that really weren't critically tested before being publicized and published. So people are having to backpedal," says Paul Weiss, a chemist at Pennsylvania State University, University Park. Adds chemist Jim Tour of Rice University in Houston, Texas, who has been one of the field's most vocal proponents: "I'm surprised it took this long to have some things confronted."

At the top of that list, Tour and others say, are questions of exactly what is going on at the heart of some de-



**Turnoff.** Models like this one for rotaxanes are "somewhere between naïve and misleading," Paul Weiss says.

CREDITS: (TOP TO BOTTOM) MARTIN HARVEY/GALLO IMAGES/CORBIS; ILLUSTRATION: C. SLAYDEN/*SCIENCE* vices advertised as molecular electronics. Some of the doubts center on work by researchers at Hewlett-Packard and the University of California, Los Angeles (UCLA). In 1999, Stan Williams, who directs quantum science research at HP Labs in Palo Alto, California, teamed up with UCLA chemists Fraser Stoddart and Jim Heath—now at the California Institute of Technology (Caltech) in Pasadena—to create transistors that used the movements of molecules called rotaxanes to turn electric currents on and off in the devices. But because the molecules were pinned between pairs of electrodes, outsiders said it was difficult to be sure what was going on. Critics suggested that the voltages used to switch the molecules might also be wreaking havoc with the metal electrodes above and below them. They proposed that when the voltage was turned on, the resulting electric field could cause metal atoms to form tiny filaments across the molecular gap between the electrodes, changing the conductivity of the material. Concerned that this might be the case, Heath split with his former HP partners and ordered his own research group to replace one of the metal electrodes with a semiconductor—a move that in theory should have prevented the metal filaments from growing.

Now it appears that those concerns were well founded. At a grantees meeting sponsored by the Defense Advanced Research Projects Agency (DARPA) in late July, Williams reported that new experiments by Mark Bockrath, another Caltech colleague, revealed that the creation and dissolution of the metal filaments between the electrodes was probably responsible for the changes in conductivity and the switching behavior. Williams maintains that the devices still qualify as molecular electronics, because the rotaxanes are acting as a one-molecule-thick insulator, an essential part of the device. But others balk at the characterization, as the molecular layer isn't directly responsible for the electronic switching.

No matter what the mechanism is or what it's called, Williams contends that commercial prospects for HP's systems are bright, and they may even offer advantages over similar molecule-based electronics. One selling point he cites is the devices' on-off ratio, a number that describes the increase in current that occurs when the voltage is turned on. Computer chipmakers typically strive for ratios of at least 50:1 to ensure that signals pierce the inevitable background noise. Heath's rotaxane-based switches manage 8:1. But the HP devices, Williams says, have an on-off ratio of 10,000:1 or more. The discovery that metal filaments are likely responsible for the switching "hasn't stopped us from building working devices," Williams says. The HP team has reported making a 64-bit memory storage device, and Williams says that it will soon report devices of much higher complexity.

Still, others say that the new insight into what's going on inside HP's devices raises at least as many questions as it answers. For example, how stable could devices that depend on metal atoms moving back and forth be in the long run? "It may not be bad, but it throws a curve ball," says David Bocian, a molecular electronics expert at UC Riverside.

New questions are arising about some of Tour's early results as well. At the July DARPA meeting, Weiss reported that tests on some of Tour's molecules revealed that a key electronic signature, originally thought to play a role in their operation, may have been an artifact. In 1999, Tour teamed up with physicist Mark Reed of Yale University and others and reported that devices containing short polymers called phenylene ethynylene molecules showed an electronic effect known as negative differential resistance, or NDR (*Science*, 19 November 1999, p. 1550). When most molecules are subjected to stronger and stronger electric voltages, they become more conductive. But when Reed and Tour placed their molecules between a pair of electrodes, they saw the reverse: The conductivity decreased as the voltage rose. That property, the researchers suggested, could be exploited to serve as an electronic switch.

**New hope.** Paul Weiss (*above*) and Jim Heath say self-criticism now will help push molecular electronics forward.

Still, questions persisted here, too. Because the molecules in Reed and Tour's experiments were also pinned between two metal electrodes, there was no way to check whether the NDR signature was really coming from the phenylene ethynylene molecules. To find out, Weiss suggested replacing the top electrode with an electrically conductive scanning electron microscope tip that would pass electrons to individual molecules, record their electronic behavior, and capture images of the molecules, all at the same time. When Weiss ran the experiments, the NDR signatures proved to be intermittent and inconsistent and were therefore probably an experimental artifact, Weiss says.

Both Weiss and Tour caution that the new results don't prove that a similar artifact caused the previous NDR readings. "They are different experimental systems," Tour says. But what the new work does show, Weiss says, is that electrically active molecules in molecular electronics experiments can behave in wildly different ways depending on whether they are surrounded by electrodes or by other materials. The implication for all molecular electronic devices: Ensuring that large networks of molecular electronic circuits all perform in an identical manner will be much harder than some of the field's boosters have implied.

Weiss's results weren't all bad news. His team did find that the phenylene ethynylene molecules could switch using a mechanism not involving NDR. The group's current hypothesis, Weiss says, is that subjecting the molecules to an electric field shifts them between two stable configurations, one of which carries current between electrodes more efficiently than the other. But it remains unclear here too how durable devices made with shifting molecules are likely to be.

Other concerns continue to dog the molecular electronics field as well. At a debate over the future of molecular electronics held last month at UCLA,* Edwin Chandross, a chemist recently retired from Lucent Technologies' Bell Labs, said that for molecular electronics devices to make it to market, researchers will have to solve a host of real-world problems. One of them, he suggested, was the likelihood that when researchers deposit hot metal atoms to form the electrodes in their materials, the atoms react with rotaxanes and other organic electronic materials, altering them in unforeseen ways.

Heath—Chandross's sparring partner in the debate—countered that numerous tests in his lab have shown that the rotaxanes survive the metal deposition process unscathed, and they continue to work as switches. But even though that may be the case, Chandross pointed out that the Caltech group's

* One-Day NanoSystems Symposium and First Cram Debate, UCLA, 22 September 2003.

CREDITS: (LEFT TO RIGHT) P. WEISS; J. HEATH devices lose their ability to switch after only a few dozen cycles. "To say 'never' is foolish, but within a decade I think we won't see large-scale memory or computing chips," Chandross says.

Heath acknowledges that high-end computer applications, such as memory and logic, won't come soon. But he stresses that it's far too early to give up on the field. "It is much easier to tear down something than build something up," Heath says. Chemists, he adds, have just begun to explore ways to increase the stability and durability of electronically active molecules. But perhaps more important, Heath adds, molecule-based systems can handle tasks silicon-based electronics simply can't touch. Several groups, for example, have created molecular electronic–based devices capable of acting as sensors and are working to wire them to larger-scale electronics. And Heath says that his group is making steady progress on developing molecule-based electronic sensors that can detect particular chemical signals inside cells.

So even if molecular electronics doesn't dethrone silicon from the top of the computing world, it may still work its way into the marketplace by carrying out tasks silicon just can't master.

–ROBERT F. SERVICE

Biodiversity

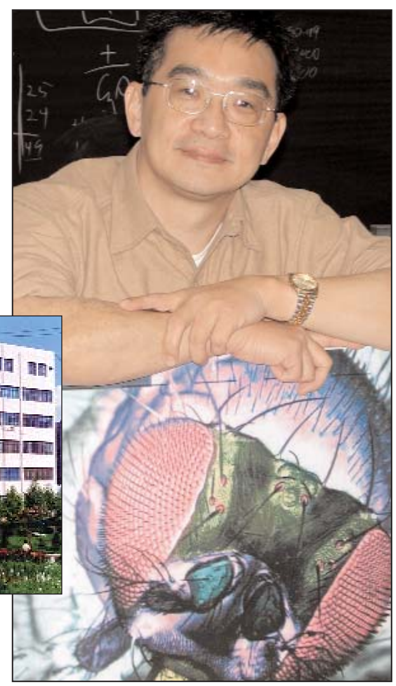
# New Chinese Center Marks a Coming of Age for Field

**The International Center for Studies of Evolution and Biodiversity will allow Chinese scientists to move beyond cataloging flora and fauna**

**TOKYO**—Shi Suhua, a botanist at Sun Yat-sen University in southern China, hit an intellectual wall as she was exploring a new area: mangrove evolution. She felt that she was over her head in population genetics and needed help. Then she learned about a workshop on the topic, taught by University of Chicago evolutionary geneticist Chung-I Wu, at the Kunming Institute of Zoology, more than 1000 kilometers away in Yunnan Province. The short course she attended in the summer of 2002 "opened a window on another world," she says.

Peer interactions of the kind that stimulated Shi's work may soon be available to hundreds more Chinese researchers, as Wu and colleagues from China, Germany, and the United States are getting ready to inaugurate a new interdisciplinary facility. The International Center for Studies of Evolution and Biodiversity (ICSEB), to be housed at the Kunming Institute, hopes to train the next generation of Chinese evolutionary biologists and ecologists and forge ties with scientists throughout the world. It will draw support from the Chinese Academy of Sciences (CAS), Germany's Max Planck Society, and the University of Chicago.

The new center, to be launched next week with a ceremony in Kunming followed by a symposium in Beijing, represents a scientific coming of age for Chinese studies of biodiversity. Chinese scientists have done an outstanding job of collecting specimens and cataloging the country's extensive flora and fauna, says biologist Uli Schwarz, director of the new Shanghai Institute for Advanced Studies (SAIS). But the time is ripe, he says, to synthesize the data and address larger interdisciplinary topics, such as interactions among species and changes in an ecological community over time. "The center will bring together what are now rather isolated efforts, provide an infrastructure for synthesis of data, and be a bridge between China and the outside," says Wu, its founding director.



**High hopes.** Chung-I Wu expects the Kunming center to promote a broader approach to biodiversity research in China.

CREDITS: (LEFT TO RIGHT) KUNMING INSTITUTE OF ZOOLOGY; UNIVERSITY OF CHICAGO

The drive to integrate findings has also prompted Fudan University in Shanghai to set up a department of ecology and evolutionary biology. Li Jin, dean of biological sciences at Fudan and a professor of genetics at the University of Cincinnati, Ohio, says that the new department will be the first of its kind in China and will cooperate closely with the Kunming center.

ICSEB's location in China's rugged southwest is no accident; the organizers placed it in Kunming to take advantage of the region's "astounding biodiversity," says Schwarz, who retired last year from the Max Planck Institute for Developmental Biology in Tübingen, Germany. SAIS, which is partly funded by the Max Planck Society, has been supporting collaborations between the Kunming Institute and a number of top Max Planck scientists, including Svante Pääbo, an evolutionary geneticist and director of the Max Planck Institute for Evolutionary Anthropology in Leipzig, and Thomas Mitchell-Olds, a plant geneticist at the Max Planck Institute for Chemical Ecology in Jena.

The new center is modeled roughly on the National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara—but without some of its resources, such as heavy-duty computing facilities. Starting with a shoestring budget of about \$100,000, Wu hopes to persuade CAS to underwrite a \$1 million budget for the center's second year of operation.

Wu says he hopes the center can offer its first round of workshops in the spring. But researchers like Shi are already benefiting. She and her group are applying what she's learned about population genetics to an analysis of genetic diversity among mangrove populations, and they hope to collaborate with Wu on a study of plant speciation. This is precisely the type of teamwork, according to Wu, that the new center is designed to foster.

–DENNIS NORMILE