there's a lot of heterogeneity in the ice core." Others argue that Priscu and colleagues have been led astray by an artifact. To keep the Vostok borehole from freezing shut, it's filled with drilling fluid. The hydrocarbons are a feast for bacteria. Says Christner: "We can think of the borehole as a 65-ton enrichment culture."

Irina Alekhina and her colleagues at the PNPI found that some microbes in the drilling fluid match species that Christner and others have found inside cores from Vostok and from the Taylor Glacier in Antarctica—microbes that they argued were native to the ice. The primary bacteria in the drilling fluid were Sphingomonas species, known contaminants of jet fuel—like the drilling fluid, mostly kerosene. "There is no indication for indigenous microbes," Alekhina concludes.

Priscu rebuts this by pointing to a study in Antarctica's McMurdo Dry Valleys in which his group found hydrocarbon-eating microbes. "The organisms are there in nature," Priscu says. "Just because we see it in the drilling fluid doesn't mean it's not native."

That debate notwithstanding, it's a mystery how microbes can survive deep in the Vostok core, which near the bottom could be 1 million to 2 million years old. If the cells had remained frozen all that time, "their genomes would accumulate enough damage that they would effectively be dead," Christner says. One microbial refuge might be the water channels between the ice crystals, says Buford Price, a physicist at the University of California, Berkeley. Christner and biophysicist James Raymond of the University of Nevada, Las Vegas, are testing whether the microbes are specially adapted to the cold life. Raymond found that one *Chryseobacterium* species from the Vostok core produces a protein that, in the lab, blocks ice-crystal growth. This suggests the bacteria are reshaping the ice around them to minimize damage, says Christner. The protein might work as antifreeze or as a seed for crystal formation to form an ice cocoon around the bacteria.

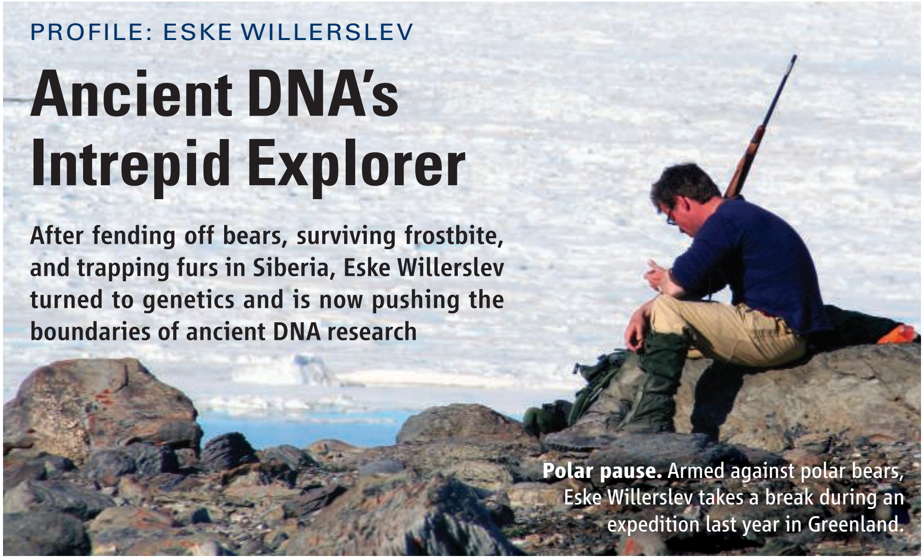
"This debate will not be resolved until Lake Vostok is sampled directly," says Vincent. When Russia breaks through, it will be like exploring a different planet. The drilling that has preceded this adventure has been "like putting pinholes in the continent," Priscu says. "We don't know what's on the bottom of that ice sheet." Well, we do know one thing: It's wet. **–MASON INMAN**

Mason Inman is a freelance journalist in Cambridge, Massachusetts.

PROFILE: ESKE WILLERSLEV

Ancient DNA's Intrepid Explorer

After fending off bears, surviving frostbite, and trapping furs in Siberia, Eske Willerslev turned to genetics and is now pushing the boundaries of ancient DNA research



Polar pause. Armed against polar bears, Eske Willerslev takes a break during an expedition last year in Greenland.

CREDIT: SVEND FULLER

COPENHAGEN, DENMARK—In the basement of the Niels Bohr Institute in Copenhagen, Jørgen Peder Steffensen pulls a puffy pale blue parka over his t-shirt and shorts and steps inside a storage locker cooled to a constant –26°C. After digging through one of the hundreds of cardboard boxes stacked inside, the bearded climatologist lifts out a dirty, plastic-wrapped cylinder of ice about 55 cm long.

The frozen chunk was cut from the bottom of an ice core drilled through Greenland's ice cap in 1981 as part of a project to look at past climate. But this core bottom was considered too disturbed by the glacier above and too contaminated with silt and dirt from below to yield much information, says Steffensen. "I've taken care of this dirty, insignificant piece of ice for 26 years," he yells as refrigeration units thunder overhead. "It was only during discussions with Eske that we homed in on a use for it."

Eske Willerslev, the director of the Centre for Ancient Genetics at the University of Copenhagen, has spent the past 8 years teasing information about the distant past from discarded ice and even less likely places. Since first extracting DNA from glacial ice in 1999, the 36-year-old biologist has pioneered what he calls "dirt DNA"—the extraction and cloning of plant and animal DNA from just a few grams of soil and ice. In 2003, he redefined ancient DNA research when he extracted the 300,000- to 400,000-year-old DNA of mammoths, bison, mosses, and much more from small samples of soil he collected from the Siberian permafrost (*Science*, 18 April 2003, p. 407). It was the oldest DNA ever discovered by more than 200,000 years.

Not long after that, Willerslev began to wonder about the ignored ice core bottoms in the building his lab shared with Steffensen's climate research group. "I did the permafrost stuff, and then suddenly it hit me: Silty ice is icy permafrost, right?" Judiciously cutting and melting the core bottoms, Willerslev and his colleagues analyzed the resulting water for signs of DNA. What Willerslev found, and reports on page 111, broke his own record for the oldest DNA ever recovered, and promises to rewrite the history of Greenland's climate. His team identified and dated genetic sequences from coniferous trees, butterflies, beetles, and a variety of other boreal forest plants—traces of ancient forests that Willerslev says covered southern Greenland perhaps as far back as 800,000 years ago.

The results have impressed his colleagues in the close-knit, highly competitive ancient DNA research community. "To go from dirty water to a forest full of insects is pretty amazing," says Matthew Collins of the University of York in the U.K. "It's spectacular how far he appears to have gone back this time."

From fur-trapping to genetics

Willerslev and his identical twin Rane grew up reading about Danish legends such as Arctic explorer Knud Rasmussen and devouring *Buddy Longway*, a popular Belgian comic book that chronicled the adventures of a fur-clad American mountain man. "I always thought I was born 200 years too late," Eske says. "Exploring America in the beginning would have fit me perfectly."

In 1991, the 19-year-old twins decided to spend their summer break in the Yakutia region of Siberia. "It was as close as you could get to unknown land," says Rane, now an anthropologist at the University of Aarhus in Denmark. "There were times when we starved and had to eat seagulls. It was very exciting at the time."

The brothers returned three summers in a row, collecting ethnographic data and filming a movie on a Siberian tribe. In 1993, a short-handed local asked Eske to spend the winter fur trapping. He readily agreed. Living like Buddy Longway "was a chance to fulfill my childhood dream," says Willerslev.

Willerslev, who spoke almost no Russian, ended up in an isolated cabin with the hard-bitten native trapper and another Russian. "We had ammunition, traps, tea, and some bread. That's it," he recalls. The team hunted moose for food, sometimes lugging home 50 kilos of meat through waist-deep snow. They were attacked by bears, and wolves picked off their hunting dogs. Willerslev once got lost alone. Only by building a fire and keeping it going all night did he manage to survive, escaping with frostbite on his face and testicles.

By Christmas, the romance of life as a trapper had completely worn off for Willerslev. But coming back to school in Denmark wasn't easy. "I was mentally changed," he says. "I tried to study for my genetics exams, but everything seemed very unimportant compared to daily survival."

Finding an ancient forest

Yet Willerslev eventually began to see opportunities that would satisfy his adventurous spirit. "I find huge satisfaction in doing exploration on a mental level instead," he says. "The 21st-century explorer is a scientist."

Interests in evolution, paleontology, and population migration soon led Willerslev to the fledgling ancient DNA field. Since no one in Copenhagen was working on ancient DNA, he improvised a self-guided course in polymerase chain reaction (PCR) techniques. He also began e-mailing with Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, a leader in the ancient DNA field. In 2004, he traveled to Oxford to work with another pioneer Alan Cooper.

The possibilities of sequencing ancient DNA had led to an initial boom in the early 1990s. But wildly optimistic claims and *Jurassic Park*–type fishing expeditions nearly discredited the field. At issue was the tremendous vulnerability of ancient DNA techniques to contamination. PCR, the development that made ancient DNA analysis possible with its ability to copy DNA fragments in a sample many millions of times, is an indiscriminate multiplier. Any speck of DNA—from a single skin cell, say, or a single pollen grain floating in a window—would throw off an entire ancient sample with strands of modern DNA. "It's a field for which the first decade was a very faltering decade," says York's Collins. "The new generation is trained to think about nothing else but ancient DNA and contamination."

Digging deep. Eske Willerslev drills for permafrost samples in Siberia.

CREDIT: SVEND FULLER; ROSS DE MACPHEE

As part of that generation, Willerslev has combined innovative techniques with exceptionally stringent measures to control contamination. Whereas the PCR primers that latch on to DNA strands are usually aimed at just one type of organism, for his 2003 permafrost work, Willerslev used primers to grab chloroplast DNA and mitochondrial DNA from a wide variety of plants and animals. This meant he had to be particularly careful about keeping modern DNA out of reagents and permafrost samples. Tests were run in independent labs to show the results could be reproduced. Using chemicals harsh enough to break open tough microbial spores without destroying already fragmented animal DNA was another challenge—one the team solved by beating the sediments with tiny beads. "We were not only applying existing techniques to new problems," he says. "We had to combine different parts of different methods into a new protocol."

Willerslev has a reputation for being unusually intense. During a trip to Beijing, "I had to convince him to take half a day off to see the Forbidden City instead of working in a dark hotel room on papers the whole time," says Michael Hofreiter, an ancient DNA specialist at the Max Planck Institute in Leipzig, Germany. The intensity has paid off. Since returning to the University of Copenhagen in 2005—he was the youngest full professor at the university—he's built a 22-person lab from scratch.

Willerslev's ancient DNA successes have implications for a wide range of fields, from climate change to ecology. For example, glacial ice older than about 60,000 years gets too compressed by the glacier's weight and movement to provide good climate data. "It doesn't bring doubt that we have older ice, we just can't directly count it," says University of Copenhagen glacier expert Dorthe Dahl Jensen, a collaborator on Willerslev's latest research. Instead, climatologists have relied on models to argue that southern Greenland was free of ice—and open to plant growth—during the Eemian, or last interglacial period, some 130,000 to 116,000 years ago. The new results contradict that scenario: An ice-free Eemian in Greenland would have replaced the 450,000- to 800,000-year-old forest DNA Willerslev found in the bottom ice cores with younger plant and animal DNA. The survival of 450,000-year-old DNA suggests that the ice has been around much longer than previously thought. If southern Greenland remained ice-covered during the last interglacial period, it could mean global warming would have to get much worse before it completely melts away the Greenland ice sheet.

And although scientists once assumed natural degradation prevented DNA older than 100,000 years from being readable, Willerslev's ice core work opens new doors. "This means we simply don't know how far we can go back," says Hofreiter, a co-author of the new *Science* paper.

Willerslev is already eyeing Antarctica, where ice temperatures that go down to –50°C may have kept DNA preserved for even longer than Greenland's relatively balmy –20°C. "Ancient DNA hasn't peaked—in the next five years, you're going to see it going even further," he says. In a forthcoming paper in *Astrobiology*, he even asks whether ancient DNA techniques could detect traces of life on other planets. It's typical, colleagues say, of Willerslev's knack for asking unexpected questions. "While I'm doing humble domestication research, he's asking about whether there's life on Mars," says researcher Joachim Burger of the Johannes Gutenberg University in Mainz, Germany.

Willerslev's passion for the lab hasn't entirely replaced his love for the great outdoors. He is due to be married on 4 August on an island with no bridges or roads in southern Sweden. "Even the priest has to take a canoe," Willerslev says happily. "It's going to be fantastic." **–ANDREW CURRY**

Andrew Curry is a freelance journalist in Berlin.

Ancient DNA's Intrepid Explorer

Andrew Curry

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