Unfrozen

There was only one way scientists could unlock the mystery of the famous Iceman. Take away his ice.

By Stephen S. Hall

Photograph by Robert Clark

Shortly after 6 p.m. on a drizzling, dreary November day in 2010, two men dressed in green surgical scrubs opened the door of the Iceman's chamber in the South Tyrol Museum of Archaeology in Bolzano, Italy. They slid the frozen body onto a stainless steel gurney. One of the men was a young scientist named Marco Samadelli. Normally, it was his job to keep the famous Neolithic mummy frozen under the precise conditions that had preserved it for 5,300 years, following an attack that had left the Iceman dead, high on a nearby mountain. On this day, however, Samadelli had raised the temperature in the museum's tiny laboratory room to 18°C—64°F.

With Samadelli was a local pathologist with a trim mustache named Eduard Egarter Vigl, known informally as the Iceman's "family doctor." While Egarter Vigl poked and prodded the body with knowing, sometimes brusque familiarity, a handful of other scientists and doctors gathered around in the cramped space, preparing to do the unthinkable: defrost the Iceman. The next day, in a burst of hurried surgical interventions as urgent as any operation on a living person, they would perform the first full-scale autopsy on the thawed body, hoping to shed new light on the mystery of who the Iceman really was and how he had died such a violent death.

Egarter Vigl and Samadelli carefully transferred the body to a custom-made box lined with sterilized aluminum foil. In its frozen state, the Iceman's deep caramel skin had a dignified luster, reminiscent of a medieval figure painted in egg tempera. With the agonized reach of his rigid left arm and the crucifixate tilt of his crossed feet, the defrosting mummy struck a pose that wouldn't look out of place in a 14th-century altarpiece. Within moments, beads of water, like anxious sweat, began to form on his body. One droplet trickled down his chin with the slow inevitability of a tear.

This was not the first time that the Iceman had been subject to intense scientific scrutiny. After Austrian authorities first recovered the mummy in 1991, scientists in Innsbruck cut a large gash across his lower torso as part of their initial investigation, along with other incisions in his back, at the top of the skull, and on his legs. It was later determined that the shallow conch of gray rock where he had been found was on the Italian side of the border with Austria, so the body and the artifacts surrounding it were relocated to Bolzano. Over the years, numerous less invasive explorations of the remains were conducted there, including x-ray and CT scan imaging studies and an analysis of the mummy's mitochondrial DNA. The most astonishing revelation came in 2001, when a local radiologist named Paul Gostner noticed a detail that had been overlooked in the images: an arrowhead buried in the Iceman's left shoulder, indicating that he had been shot from behind. Later work by Gostner and his colleagues with more powerful CT imaging devices revealed that the arrow had pierced a major artery in the thoracic cavity, causing a hemorrhage that would have been almost immediately fatal. The oldest accidentally preserved human ever found was the victim of a brutally efficient murder.

Other scientists filled in biographical details. Analysis of chemical traces in his bones and teeth indicated that Ötzi, as he is also called, grew up northeast of Bolzano, possibly in the Isarco River Valley, and spent his adulthood in the Venosta Valley. Pollen found in his body placed his final hours in the springtime, and his last hike probably along a path up the Senales Valley toward an alpine pass just west of the Similaun Glacier. Close examination of his hand revealed a partially healed injury, suggestive of a defensive wound from an earlier fight. DNA analysis of food remnants found in his intestines—his stomach appeared to be empty—indicated that sometime before he met his demise, he had eaten red meat and some sort of wheat. Putting these facts together, scientists theorized that adversaries had an altercation with the Iceman in the valley south of the pass, chased him, and caught up with him on the mountain, where the body was discovered more than 5,000 years later.

It was a good story that fit the evidence—until Gostner took a closer look at the Iceman's guts. Though he had retired, the radiologist kept studying the CT scans at home as a kind of hobby, and in 2009 he became convinced that scientists had mistaken the Iceman's empty colon for his stomach, which had been pushed up under his rib cage and appeared to Gostner to be full. If he was right, it meant the Iceman had eaten a large, and presumably leisurely, meal minutes before his death—not the sort of thing someone being chased by armed enemies would likely do.

"Gostner came over and told us he thought the stomach was full," said Albert Zink, director of the EURAC Institute for Mummies and the Iceman in Bolzano, who oversaw the autopsy last November. "And we thought, OK, then we have to go inside and sample the stomach." After further thought, Zink and his colleagues drew up a more ambitious plan: a head-to-toe investigation involving seven separate teams of surgeons, pathologists, microbiologists, and technicians. Perhaps most remarkable, this choreographed intervention would be accomplished without making any new incisions in the Iceman's body. Instead, the scientists would enter the body through the "Austrian windows"—their name for the overenthusiastic cuts made by the initial investigators.

"This will happen once," Zink said, "and then never again for many, many years."

"This is the brain," announced neurosurgeon Andreas Schwarz, as he maneuvered a neurological endoscope into the top of the Iceman's head. Like the other scientists in the room, Schwarz was wearing 3-D glasses, and as he inched the instrument deeper inside the skull, a blurry 3-D image appeared on a computer monitor. It was a little after 1 p.m., and by that point the Iceman had already undergone six hours of poking, probing, gouging, and sample gathering. The surgical teams had taken snippets of muscle and lung. They had bored a hole in his pelvis to collect bone tissue for DNA analysis. They had rummaged around his thorax, trying to get close to the arrowhead and the tissue around it. They had even plucked some of his pubic hair. His skin had lost its luster and had a dull, leathery look, like a chicken wing left in the freezer too long.

Now they were peeking inside his brain to see if a mysterious shadow on a previous CT image might be an internal clot, or hematoma, at the rear of the skull, indicating a blow to the head. But the operation was not going smoothly. Schwarz's endoscope kept bumping into ice crystals that blurred the camera lens. After an hour, the neurosurgery team finished up, not entirely sure whether they had obtained a viable sample.

The initial attempts to explore the stomach were also frustrating. Peter Malfertheiner, of the Otto-von-Guericke University of Magdeburg, tried to insinuate an endoscope down the Iceman's throat into the stomach, but five millennia of atrophy and mummification blocked the way. Egarter Vigl stepped in with a less delicate approach. Using the large Austrian window at the lower end of the torso, he stuck a gloved hand into the Iceman's gut. He pulled out two large chunks of undigested food, then switched to a kitchen spoon and scooped several more ounces from the Iceman's very full stomach.

By the end of the day, the laboratory freezer brimmed with 149 biological samples—"enough for about 50 papers," quipped one of the biologists. As soon as the autopsy concluded, Samadelli lowered the temperature in the laboratory below freezing. The next morning he and Egarter Vigl spruced up the body with a fine spray of sterilized water, which froze on contact. Then they slid the Iceman back into his high-tech igloo and closed the door.

The autopsy had taken about nine hours; analysis of the material gleaned will take years. The first revelations were disclosed in June, when Zink and his colleagues presented some of their initial findings at a scientific meeting. Thanks to the DNA in a tiny speck of pelvic bone culled during the autopsy, the Iceman has joined the company of renowned biologists James D. Watson and J. Craig Venter as one of a handful of humans whose genomes have been sequenced in exquisite detail.

The genetic results add both information and intrigue. From his genes, we now know that the Iceman had brown hair and brown eyes and that he was probably lactose intolerant and thus could not digest milk—somewhat ironic, given theories that he was a shepherd. Not surprisingly, he is more related to people living in southern Europe today than to those in North Africa or the Middle East, with close connections to geographically isolated modern populations in Sardinia, Sicily, and the Iberian Peninsula. The DNA analysis also revealed several genetic variants that placed the Iceman at high risk for hardening of the arteries. ("If he hadn't been shot," Zink remarked, "he probably would have died of a heart attack or stroke in ten years.") Perhaps most surprising, researchers found the genetic footprint of bacteria known as *Borrelia burgdorferi* in his DNA—making the Iceman the earliest known human infected by the bug that causes Lyme disease.

The autopsy results have also rewritten the story of the Iceman's final moments. The neuroscientists determined that blood had indeed accumulated at the back of the Iceman's brain, suggesting some sort of trauma—either from falling on his face from the force of the arrow, Zink speculated, or perhaps from a coup de grâce administered by his assailant. DNA analysis of the final meal is ongoing, but one thing is already clear: It was greasy. Initial tests indicate the presence of fatty, baconlike meat of a kind of wild goat called an alpine ibex. "He really must have had a heavy meal at the end," Zink said—a fact that undermines the notion that he was fleeing in fear. Instead, it appears he was resting in a spot protected from the wind, tranquilly digesting his meal, unaware of the danger he was in.

And of course, unaware of the intense attention awaiting him far in the future. The Iceman might be the most exposed and invaded person who ever walked the planet. "There were moments yesterday," Zink said in a soft, almost surprised voice, "when you felt sorry for him. He was so…*explored*. All his secrets—inside him, outside him, all around him—were open to exploration." He paused and added, "Only the arrowhead remains inside him, as if he's saying, This is my last secret."

Stephen S. Hall last visited the Iceman in the July 2007 issue of the magazine. Robert

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