Save paper and follow @newyorker on Twitter

A REPORTER AT LARGE
NOVEMBER 16, 2015 ISSUE

THE INVISIBLE LIBRARY

Can digital technology make the Herculaneum scrolls legible after two thousand years?

BY JOHN SEABROOK

Left: Multispectral imaging reveals erased ancient writing. Right: A cross-section of a carbonized scroll from Herculaneum.

ILLUSTRATION BY CHAD HAGEN; SOURCE: COURTESY OWNER OF THE ARCHIMEDES PALIMPSEST (LEFT); UNIVERSITY OF KENTUCKY VIS CENTER (RIGHT)

It was a warm day in Paris, and the library of the Institut de France was stuffy and hot. Daniel Delattre, a distinguished French papyrologist, did not remove his suit jacket. The institute, which includes the Académie Française, is a jacket-and-tie sort of place.

Delattre, who is sixty-eight years old and has a dreamy, lost-in-the-vale-of-academe manner, was contemplating a small wooden box on the table in front of him which was labelled "Objet Un." There are thousands of rare objects in the institute's library; the fact that whatever was inside the box was Object One suggested that it was of some importance. An ornately hand-lettered card was taped to the outside. It said, in French, "Box containing the remains of papyrus from Herculaneum"—the Roman town destroyed, along with its larger neighbor, Pompeii, in the eruption of Mt. Vesuvius in A.D. 79.

The papyrus scrolls of Herculaneum, which were discovered in 1752, have long fascinated and frustrated lovers of antiquity. They were found in an elaborate villa buried almost ninety feet deep by the volcano—this archeological wonder has been known ever since as the Villa dei Papiri. At least eight hundred scrolls were uncovered; they constitute the only sizable library from the ancient world known to have survived intact. Some were found stacked on shelves in a small room; others were elsewhere in the villa, packed in *capsae*, travelling boxes for the scrolls, presumably in preparation for flight.

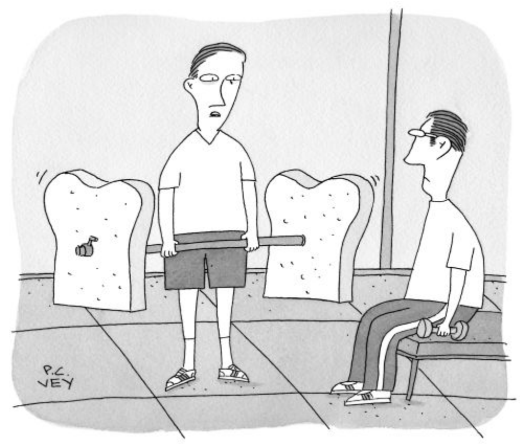
Given the splendor of the villa, and the masterly bronze sculptures found in its ruins, the learned world assumed that the library would contain vanished classics. One could dare hope for one or two of the lost histories of Livy, of whose hundred and forty-two books on the history of Rome only thirty-five survive. Or perhaps one of the nine volumes of verse written by Sappho, the Greek poet; only one complete poem remains. By some estimates, ninety-nine per cent of ancient Greek literature has been lost, and Latin has not fared much better. Among those works we know are missing are Aristotle's second volume of the Poetics, which was on comedy; Gorgias' philosophical work "On Non-Existence"; the four missing books of the Roman historian Tacitus' Annals, covering Caligula's reign and the beginning of Claudius'; Ovid's version of "Medea"; and Suetonius on the Greek athletic games. (His "Lives of Famous Whores" also, sadly, has not survived.) Greek tragedy has been decimated. According to the Suda, the tenth-century Byzantine encyclopedia of classical culture, Euripides wrote as many as ninety-two plays; eighteen survive. We have seven each from Aeschylus and Sophocles, who wrote about ninety and a hundred and twenty, respectively. "And that's just the big three of tragedy," the writer and classics professor Daniel Mendelsohn told me. "Of the thousand that were likely written and performed during the hundred-year heyday of tragedy, we have only thirty-three extant plays—that's about a three-per-cent survival rate."

Delattre's dream has been to recover something of the lost works of Epicurus (341-270 B.C.), the Greek philosopher whose thought has been the focus of his life's study, and whose writings are known only through secondary sources.

"Basically, whatever your specialty is, that's what you want to find in the scrolls," David Sider, a professor of classics at N.Y.U. and the author of "The Library of the Villa dei Papiri at Herculaneum" (2005), told me.

But that's the problem. In trying to read the scrolls, scholars and curators have invariably damaged or destroyed them. The Herculaneum papyri survived only because all the moisture was seared out of them—uncharred papyrus scrolls in non-desert climates have long since rotted away. In each scroll, the tightly wrapped layers of the fibrous pith of the papyrus plant are welded together, like a burrito left in the back seat of a car for two thousand years. But, because the sheets are so dry, when they are unfurled they risk crumbling into dust.

During the past two hundred and fifty years, an array of methods and materials have been used on the easier-to-unwrap scrolls, including rose water, mercury, "vegetable gas," sulfuric compounds, and papyrus juice—most of which have caused grievous harm to the delicate plant material on which the text is inscribed. Scores of scrolls have been badly damaged or destroyed, ruined by the same uniquely human impulse that went into making them—the desire to read.



"Never eat anything you can't lift over your head."

Before addressing Objet Un, Delattre opened another box, containing pieces of two scrolls (the institute has six altogether) that had suffered a misguided attempt to read them in 1985. There were hundreds of fragments, organized within a set of smaller boxes. They resembled scraps of dried mud. But if you looked closely you could see tiny Greek letters on the warped surfaces, made by a scribe two thousand years ago—an electrifying jolt of handwritten human communication from the ancient world.

Delattre explained that the two ill-fated scrolls had been transported to Naples, where they were treated with a mixture of ethanol, glycerin, and warm water, which was supposed to loosen the folds. One scroll was peeled apart into many fragments; the other dried up and then, like a disaster in slow motion, split apart into more than three hundred pieces. "Well," Delattre murmured, "it simply exploded." He shook his head sadly.

How did the institute come by six scrolls in the first place? Delattre explained that, by 1800, the Herculaneum scrolls had become instruments of diplomatic and political power. In 1802, Ferdinand, the Bourbon king of Naples and Sicily, "gave" six of the scrolls to Napoleon, who was threatening to invade Naples. Napoleon housed them in the Institut de France, which he reorganized in 1803 into what would later become the five academies that form the institute today. The collection grew around the scrolls; that's why the box Delattre showed me was labelled "Objet Un." But the scrolls did not satisfy Napoleon for long; capitalizing on victory in the Battle of Austerlitz, France invaded Naples in 1806, forcing Ferdinand and his court to flee to Sicily, leaving the scrolls in nearby Portici, where they were housed in a royal museum. When Britain helped restore Ferdinand to the throne, in 1815, he was so grateful that he is rumored to have bestowed eighteen scrolls on the British Prince Regent, later George IV, who in turn gave the Neapolitan court eighteen live kangaroos from the British colony of New South Wales. Some of these scrolls ended up in Oxford, but a few are still unaccounted for. The fate of the kangaroos is even less clear.

Delattre placed his hands on the box containing Objet Un. But he did not open it. He prepared his guests for the worst—the shock of seeing the body in the morgue. When he finally lifted the lid, you saw why. Swaddled in thick cotton was what appeared to be a human turd.

One glance at the scroll was enough to be sure there was no hope it could ever be unwrapped physically. But what about virtually?

Herculaneum was situated on the southwestern flank of Vesuvius, closer to the volcano than Pompeii, to the southeast, and it was destroyed in a different way. Pompeii was slowly buried under falling pumice and ash, carried by the prevailing wind for several days, while Herculaneum was flash-seared by volcanic phenomena called pyroclastic flows and surges—successive waves of superheated gas and rock that overtook the city rapidly, eventually sealing everything under a deep layer. In a famous letter to Tacitus, Pliny the Younger, who witnessed the eruption from across the bay, at Misenum (his uncle, the naturalist and philosopher Pliny the Elder, died in the catastrophe), described seeing "a horrifying dark cloud, ripped by sudden bursts of fire, writhing back and forth."

For centuries, it was believed that most of the residents of Herculaneum had escaped. It was not until 1980 that a grisly discovery was made: gathered together by the harbor, in what had been boat sheds, were some three hundred skeletons, of people who had apparently been waiting for rescue. The pyroclastic flow carbonized organic matter such as wood, food, sewer contents, and scrolls; little trace of these things was found at Pompeii, where almost everything organic eventually decayed. Joseph Jay Deiss, in his evocative book "Herculaneum: Italy's Buried Treasure," describes an urban tableau that is frozen in time: "Luncheon still waits on tables. . . . The sick boy in the shop of the gem-cutter lies in his bed, his lunch of chicken uneaten. The baby remains in the cradle, a pathetic little heap of carbonized bones."

The Villa dei Papiri is thought to have been built by Julius Caesar's father-in-law, Lucius Calpurnius Piso Caesoninus, a wealthy statesman who was a consul of the Roman Republic in 58 B.C. The huge house, at least three stories tall, sat beside the Bay of Naples, which at that time reached five hundred feet farther inland than it does today. The villa's central feature was a long peristyle—a colonnaded walkway that surrounded the pool and gardens and sitting areas, with views of the islands of Ischia and Capri, where the Emperor Tiberius had his pleasure palace. The Getty Villa, in Los Angeles, which was built by J. Paul Getty to house his classical-art collection, and opened to the public in 1974, was modelled on the villa and offers visitors the opportunity to stroll along the peristyle themselves, as it was on that day in 79.

Buried four times deeper than Pompeii, Herculaneum was forgotten. Its name disappeared from history. In 1709, more than sixteen centuries after the eruption, workmen digging a well in the town of Resina hit the upper tier of Herculaneum's ancient theatre, a structure that once seated twenty-five hundred. The excavations that followed, which were closer to treasure hunts than to archeological digs, were mostly carried out under the auspices of the royal House of Bourbon, members of which ruled France and much of southern Europe, including Spain and parts of present-day Italy. The Villa dei Papiri was discovered in 1750, and its excavation was supervised by a Swiss architect and engineer named Karl Weber, who dug a network of tunnels through the subterranean structure and eventually drew up a map of the villa's layout. The architects of the Getty Villa based their design on Weber's plan.

The discovery of the first cache of scrolls, in October, 1752, was reported the following month in a letter sent by Camillo Paderni to Dr. Richard Mead. Paderni was a painter and copyist from Rome, who had come to Herculaneum to reproduce some of the villa's wall paintings. Somehow he managed to get Charles, Ferdinand's father, to appoint him "keeper" of the royal museum at Portici, where the sculptures and the scrolls were kept. Mead was a distinguished British physician, a fellow of the Royal Society, and a noted book collector, with a library of more than a hundred thousand volumes in his house in Bloomsbury, which was dispersed in an epic, fifty-six-day auction after his death, in 1754. In corresponding with Paderni, Mead may have hoped to obtain the ultimate prize before he died—a newly discovered great work of classical literature, of which there existed but a single copy.

Paderni's letter was read to the Royal Society, which met monthly in Crane Court, off Fleet Street, in February of 1753, and was published in the society's "Philosophical Transactions" for that year. The news of a recently discovered ancient library captivated Europe. The scrolls, together with the bronze statues, and the opportunity to descend into the theatre of Herculaneum, were the reason that Naples became a stop on the eighteenth-century gentleman's Grand Tour. ("See Naples and die.") Who could resist the chance to peer into a lost masterpiece from antiquity? The scrolls must have enhanced Charles's stature; in 1759 he assumed the throne of Spain, leaving his son Ferdinand to rule Naples and Sicily.

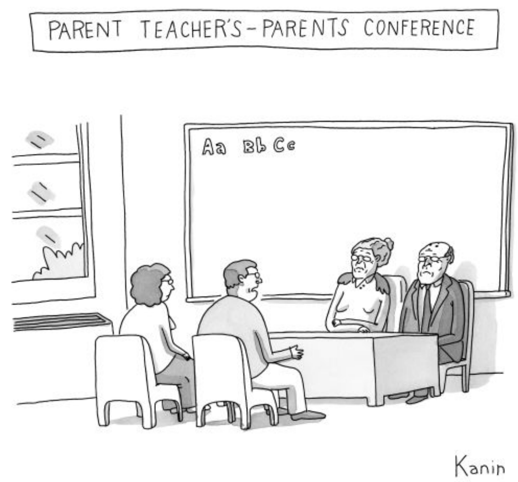
Charles told Paderni to see about opening the scrolls, and the keeper, whom the historian Charles Seltman described as "a lazy sycophant of a man," saw to it. In his letter to Mead, Paderni noted that the papyrus had "turn'd to a sort of charcoal, so brittle, that, being touched, it falls readily into ashes." He continued, "Nevertheless, by his Majesty's orders, I have made many trials to open them, but all to no purpose; excepting some words." As David Blank, of U.C.L.A., a prominent American papyrologist, told me, Paderni at first simply cut the scrolls in half lengthwise. He removed the less charred *midollo*, or marrow, and then scraped away at the outer layers—the *scorza*, or bark, as it was called—until writing could be seen. (Only later did he realize that the *midollo* was, in fact, the most legible part.) Blank said, "Charles wanted visible writing that he could show to his important visitors."

In 1753, Charles brought in Father Antonio Piaggio, from the Vatican Library, who built a machine to unwrap the scrolls, very slowly, at the rate of a centimetre an hour—the so-called Piaggio Machine. Johann Winckelmann, the German archeologist and art historian, described Piaggio's work in his "Letter on the Herculaneum Discoveries," published in 1762:

> It is incredible to imagine what this man [Piaggio] contrived and executed. He made a machine, with which, (by the means of certain threads, which, being gummed, stuck to the back part of the papyrus, where there was no writing), he begins, by degrees, to pull, while with a sort of ingraver's instrument he loosens one leaf from the other, (which is the most difficult part of all).

It was four years before the first scrolls were successfully unwrapped, but eventually Piaggio managed to unwrap fifty more, some dozens of feet long, with his machine. And what lost masterpieces did he reveal? Not Livy, or Sappho, or Simonides, the Greek lyric poet whom William Wordsworth invoked in his poem "September, 1819":

> O ye, who patiently explore
> The wreck of Herculaneum lore,
> What rapture! could ye seize
> Some Theban fragment, or unroll
> One precious, tender-hearted scroll
> Of pure Simonides.



"Your son is teaching third grade at a second-grade level."

Most of the scrolls, including the first one unwrapped by Piaggio, "On Music, Book 4," were written by the same person—a minor Greek poet and philosopher named Philodemus. Who was he? A nineteenth-century commentator called him "an obscure, verbose, inauthentic Epicurean from Cicero's time." Thanks to decades of painstaking work by Father Piaggio and his successors, we have the final book of Philodemus' multivolume "On Music," large parts of his "Rhetoric," and his "On the Stoics," "On the Good King According to Homer," "On Flattery," "On Wealth," and "On Anger," among many others. In some cases, there are multiple copies of the same book.

Philodemus was born about two hundred and thirty years after Epicurus, and was a member of the Athens school of Epicurean thought. He also wrote epigrams, of which Cicero speaks archly (he calls him a "Greekling"). Several of these are dedicated to Piso, Caesar's father-in-law. Like many late-Republic Roman aristocrats, Piso was a follower of Epicurus, and he seems to have been Philodemus' patron. At some point during the Roman takeover of Athens, Philodemus is believed to have moved to Herculaneum, bringing his library with him. The villa thought to have been built by Piso could have held Philodemus' library. (The reasoning for both these theories is circular: because Philodemus was connected to Piso, and because the works were found in a villa that few Romans other than Piso were rich enough to build, the house probably belonged to Piso, and Piso's villa could have held Philodemus' library.)

Still, among the hundreds of unopened scrolls, there might be great works that Philodemus was describing; namely, complete copies of Epicurus' original writings. Among the Villa dei Papiri scrolls are many that were written in Latin; these were mostly found in the *capsae*, presumably because someone was trying to save them, but they are more likely to contain literary works by Roman writers. And the Latin papyri are in even worse condition than the Greek ones. Sarah Hendriks, a young

Australian papyrologist whom I met in the National Library in Naples, who works on the Latin scrolls, said, "While it is relatively easy to find individual letters, finding whole words can be only a weekly or monthly occurrence at most. Whole lines of text are extremely rare. I often look with envy at the Greek papyri!"

In 2005, Delattre attended a meeting in Oxford of the Friends of Herculaneum Society, a group of professional papyrologists and amateur Herculaneum enthusiasts. The keynote speaker was Brent Seales, a software engineer who is the head of the computer-science department at the University of Kentucky. He gave a talk about the possibility of "virtually unwrapping" the scrolls, using a combination of molecular-level X-ray technology, spectral-imaging techniques, and software designed by him and his students at the university.

Digital restoration—the application of modern imaging technology to the reading of ancient manuscripts—is not exactly Seales's idea, but it has become his mission. His work has brought him renown in papyrological circles, and has made him something of a celebrity on campus in Lexington, where the school newspaper regularly reports on his progress. Seales does much of his manuscript work at the university's Center for Visualization and Virtual Environments, where he is the director.

"The idea is that you're not just *conserving* the image digitally—you can actually *restore* it digitally," Seales explained, in his earnest, go-getter way. The potential struck him in 1995, when he was assisting Kevin Kiernan, an English professor, on a digital-imaging project involving the only extant copy of "Beowulf," the medieval masterwork, which is in the British Library. The manuscript was damaged in a fire in 1731. The Kentucky team used a variety of techniques, including one called multispectral imaging, or MSI—developed by NASA for use in mapping mineral deposits during planetary flyovers—to make the letters stand out from the charred background. The basic principle is that different surfaces reflect light differently, especially in the infrared part of the spectrum. Inked letters will therefore reflect at different wavelengths from those of the parchment or vellum or papyrus they are written on.

As Seales worked on more manuscripts, he realized that what he had thought of as a two-dimensional problem was really three-dimensional. As a writing surface ages, it crinkles and buckles. If Seales could design software that reverse-engineered that aging process with an algorithm—"something like the stuff that lets you see the flag waving in reverse," as he put it—he might be able to virtually flatten the manuscript. Back in Kentucky, Seales and his team put their concept to the test with King Alfred the Great's Old English translation of "The Consolation of Philosophy," by Boethius, which is also in the British Library. They studied the material science of the vellum that the medieval scribe had used, and, by modelling that on the computer, Seales was able to virtually smooth out the manuscript, making some letters visible for the first time.

Seales's name got around to the curators of collections containing badly damaged manuscripts; he was the guy who could read the unreadable. "I came to think of it as the 'impossible scenario,' " he said. "Every time we'd go to a collection, people would pull out stuff they couldn't do anything with, and say, 'O.K., you can do something with that, but what about this?' "

Richard Janko, a classical scholar at the University of Michigan and a leading papyrologist, heard of Seales's work and talked to him about the Herculaneum papyri—the ultimate impossible scenario, because reading them meant not only flattening deformed surfaces but also seeing inside scrolls that had never been unwrapped at all. In 1999 and 2000, a team from Brigham Young University had, in fact, conducted an MSI study on some of the scrolls that had already been opened. They achieved spectacular results on the surfaces. But they could do nothing with the hundreds of scrolls that hadn't been unrolled.

Seales, in his Oxford talk, proposed putting an unopened scroll inside a CT scanner. CT—computed tomography—is the X-ray technology used to create 3-D images of human bones and organs. More recently, CT has been applied to mummies and a variety of other archeological artifacts, as well as to fossils. Because X rays pick up the presence of metals, they have worked well on medieval manuscripts, whose ink contains iron. To dramatize what might be possible, Seales had made his own scroll, using a fresh sheet of papyrus on which he had written symbols with iron-gall ink, and which he then rolled up three times. He scanned it, and the result was an arresting simulation of images that depicted the scroll unrolling and the symbols showing clearly on the surface.

But no one had ever done a 3-D scan on an ancient Herculaneum papyrus scroll before. "And I'm this naïve American," Seales told me. "I think all I have to do is ask if I can scan one and they'll say yes." The National Library in Naples, where the vast majority of the scrolls are kept, eventually rejected his proposal.

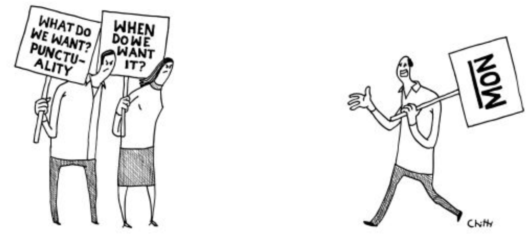
After the talk, Delattre introduced himself to Seales, and explained that there were six scrolls in Paris. Seales had not known about them. "*Mais oui*," Delattre said. And he, Daniel Delattre, was the primary scholar.

Daniel Delattre learned Latin by the age of eleven and ancient Greek a few years after that. "Those were the two subjects I preferred," he told me. He met his wife, Joëlle Delattre-Biencourt, in high school, and they fell in love with antiquity and with each other. After attending the University of Lille, Delattre taught high-school classics and began working on his doctoral thesis, on the theology of Epicurus, who is best known for the doctrine that the goal of life is pleasure.

Epicurus also posited that the world is made of atoms—the *atomos* (indivisible) elements of matter. "Epicurus says we are in an atomistic system," Delattre explained. "Everything that occurs is the result of the atoms colliding, rebounding, and becoming entangled with one another, with no purpose or plan behind their motions." For Delattre, Epicureanism encompasses physics and ethics, a complete world view that he both studies and emulates. As he gets older, he told me, he finds it comforting to think that "when we die there is a dissolution of the aggregate, and the atoms come together to make a new thing. And so we have nothing to fear from death; there is no punishment, no Hell—we simply cease to exist." There are gods, "but they are very quiet and very happy and don't interfere with human activities." Epicurus influenced the first-century-B.C. Roman poet and philosopher Lucretius, who wrote "On the Nature of Things," the epic poem that was rediscovered in a monastic library in 1417 by Poggio Bracciolini, a find that Stephen Greenblatt, in his 2011 Pulitzer Prize-winning book, "The Swerve: How the World Became Modern," credits as being a founding document of the Renaissance.

Not a single one of Epicurus' philosophical texts has survived; aside from a few fragments, his only preserved words come from two collections of sayings and three letters known only from secondary sources. One letter, as reproduced by Diogenes Laertius, an early biographer of the Greek philosophers, reads, "I have written this letter to you on a happy day to me, which is also the last day of my life. For I have been attacked by a painful inability to urinate, and also dysentery, so violent that nothing can be added to the violence of my sufferings. But the cheerfulness of my mind, which comes from the recollection of all my philosophical contemplation, counterbalances all these afflictions."

Delattre didn't plan to become a papyrologist, but one of the Philodemus scrolls unwrapped by Father Piaggio in the eighteenth century was on the subject of Epicurus and the gods, and he wanted to read it. He went to the National Library in Naples. "When I saw the opened sheets of carbonized papyrus for the first time, it was very impressive. For me, the writing was very vivid. I felt I was in direct contact with that time. And when I read the name Plato for the first time in the text it made me very emotional. I became a papyrologist at that moment."



Papyrology is a study that combines aspects of textual scholarship, philology, and archeology. It requires Olympian patience to find letters and words amid such badly damaged material, and immense learning to divine the meaning within. It's unusual to get three words in a row without lacunae. Compounding the difficulty is the fact that scribes wrote Greek without spaces between words. A single line can easily take six months to decipher. Sometimes educated guesses about missing bits are wrong, causing the reader to arrive at different meanings from what was intended. One of the revelations following the Brigham Young MSI studies was how wrong many of the earlier readings of the scrolls were. Some editors were essentially making up their own texts.

"Papyrologists are a special breed," Anthony Grafton, a professor of Renaissance and Reformation history at Princeton, says. "They work with really badly damaged manuscripts. But they live with the promise of finding something really new—which is very rare in most classical scholarship." There, marginalia is the only hope.

Delattre spent a year in the National Library, where, in addition to his thesis research, he started working on a new edition of part of Philodemus' "On Music, Book 4," the first of the scrolls opened with Piaggio's machine. That was in 1985. He finished two decades later. Along the way, he made a stunning discovery: previous editions of "On Music" had the sequence of some of the detached leaves of the scroll backward. Delattre's edition, published in 2007, corrected the problem and has caused papyrologists to reëvaluate the entire Philodemus canon. Richard Janko, in a review in the *Journal of Hellenic Studies*, called it "pioneering work of the first order."

Delattre became the official editor of the six scrolls in the Institut de France in 2003, a year after the two damaged scrolls returned from Naples. Working at the Sorbonne and at the Institut de France, he has been preparing an edition of one of them, assisted by various students and colleagues; his wife, a retired philosophy professor, is also part of the team. Delattre has been trying to figure out the correct order of the pieces, read them, and publish an edition before he dies, a goal that he says is impossible, because the project "takes an infinite time. Our human scale is not the scale of the scrolls." He is far enough along in the book to be sure that it is yet another work by Philodemus: "On Slander."

In the course of obtaining permission to scan the Paris scrolls, Seales had to give a presentation, in French, to the Académie des Inscriptions et Belles-Lettres, an academy within the Institut de France. "I just wanted to run and hide before that talk, I was so nervous," he said. His request was approved. In 2009, with a grant from the National Science Foundation, Seales had a portable CT scanner brought to the institute, and he spent four weeks scanning two unopened scrolls.

In the resulting images, the folds in the papyrus look cellular, almost biological. Here and there, grains of sand, perhaps trapped in the scrolls when a sandy bather had finished reading, are clearly visible. Seales proposed using these as orientation points for navigating within the labyrinthine volumes.

But the CT scans did not show any letters. There was lead in the ink, but only trace amounts. Though the ink did contain carbon, it did not stand out against the carbon in the blackened papyrus. Seales said, "We hoped that we could look for calcium or other trace compounds in the ink that might help us tease out the writing, but that didn't work out."

In 2010, at a digital-restoration conference in Helsinki, Seales met Uwe Bergmann, a physicist at Stanford. Seales was familiar with Bergmann's work on the Archimedes Palimpsest. In the early nineteen-hundreds, scholars had discovered that two lost works of Archimedes, the third-century-B.C. Greek mathematician and inventor, lay beneath a medieval religious text; a third work, which was also found, had survived in Latin translation. The palimpsest was probably made in Jerusalem, in the thirteenth century. Parchment was in short supply there, and a scribe had scraped away at a tenth-century copy and written over it. Using MSI, researchers could see the titles—"Stomachion," "The Method of Mechanical Theorems," and "On Floating Bodies"—but they couldn't decipher much of the text beyond what was visible to the naked eye.

When Bergmann read about the palimpsest, in an article in *GEO* that his mother had given him, he immediately thought of employing a synchrotron, a type of particle accelerator—a machine that uses magnets and microwaves to move subatomic particles at almost the speed of light. Some accelerators are linear, others are ring-shaped; Stanford has both kinds. In a synchrotron, the particles' trajectory is altered to produce powerful X rays, which can be focussed into a beam about the width of a strand of hair. With this beam, it is possible to produce images of molecular structure; the synchrotron has become an immensely useful tool for the drug and electronics industries in developing and studying new compounds.

The beam can be "tuned" to look for particular elements. "The article said that the ink the scribes had used contained iron," Bergmann said. "That's one thing we do at the Stanford synchrotron. We measure iron and other metals in proteins—extremely small concentrations of iron."

"I cooked us a lovely dinner for two—you could at least do the dishes!"

DECEMBER 19, 2011

Once he obtained access to the palimpsest, Bergmann used X-ray fluorescence imaging, or XRF, in the synchrotron to get pictures of the iron-based molecules in the ink. Unlike MSI, XRF is sensitive to individual elements. Different elements emit characteristic wavelengths of light when the X rays hit them; by zeroing in on iron, Bergmann was able to see the letters. "What had been invisible for centuries was made, right before our eyes, visible," he said, in an interview published by the Department of Energy. "Line by line, Archimedes' original writings began to come to life, literally glowing on our screens. It was the most amazing thing."

At the Helsinki conference, Seales pointed out to Bergmann that XRF wouldn't work on the unopened scrolls, because it doesn't penetrate deep enough; it would scan only the outer layers. "And Uwe didn't bat an eye," Seales told me. "He said, 'Phase contrast, man.' "

COURTESY OWNER OF THE ARCHIMEDES PALIMPSEST

Phase contrast, or XPCT, is another microscopic-imaging tool made possible by synchrotrons. Because XPCT can penetrate surfaces much more deeply, it is used to measure density. A detector behind the sample being imaged captures the changing intensity of the beam as it passes through different atomic densities, which would allow the scroll researchers to map the indentations left by the stroke of the pen.

Bergmann and Seales were considering using Stanford's synchrotron, but the Institut de France would not allow the scrolls to leave the country. There was a synchrotron just outside Paris, but "beam time" there cost about twenty-five thousand dollars a day, and Seales was unable to get a grant to pay for it.

By now, seeing inside an unopened scroll had become something of a quest for Seales. "We'll read the scrolls," he told me in an e-mail. "It's been ten years and look at all we have achieved. From impossible to plausible, even probable. From the wreck of Herculaneum lore, we've created a body of systematic, scientific work." It was only a question of getting the beam time.

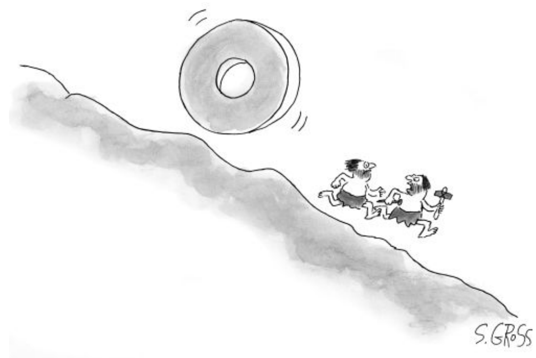
Then comes the swerve—a central concept in Epicurean physics. If all matter is made of atoms, and if atoms move through the void according to their own fixed laws, then everything that happens to us is predestined. But, Delattre explained, "There would be no freedom, and for Epicurus we are free, so he wanted to introduce the possibility of this slight deviation." Sometimes the atoms swerve slightly out of their natural trajectory, causing unplanned collisions with unpredictable consequences—not unlike what particles actually do in a synchrotron. (The particle accelerator is an Epicurean invention.) "Lucretius calls this the *clinamen*, which means 'deviation' in Latin—the atoms' tendency to change direction slightly," Delattre added. On a vast scale, this creates an inherently unpredictable universe in which man freely chooses his own path.

The swerve in Seales's plans was Vito Mocella, a physicist at the Institute for Microelectronics and Microsystems, in Naples, who also happened to be interested in the scrolls. In 2007, he was on a family holiday in Capri at the same time that a conference of Herculaneum papyrologists was being held at his hotel. He overheard one of them talking about the problems with reading the scrolls and, he told me, he thought of phase contrast, which he uses regularly in his work on new drug compounds. "I thought that would perhaps solve the problem," he said.

Mocella is a native Neapolitan; he looks a bit like John Lennon might have if he'd had an Italian wife who kept him well fed. He remembers seeing the scrolls for the first time in the National Library when he was ten. "I thought it was strange that the Piaggio Machine was still the best method of opening the scrolls," he told me. "That machine was two hundred years old!"

Mocella had no problem getting beam time in a synchrotron. An old friend from his graduate-school days, Claudio Ferrero, was the head of the Data Analysis Unit at the European Synchrotron Radiation Facility, in Grenoble. Ferrero thought that he could get the E.S.R.F. to donate some beam time if Mocella could get his hands on a scroll. Ferrero described the amazing results that paleontologists were getting with fossilized eggs—the X-rays showed the shape and the density of the embryos inside. He thought that phase contrast might be able to pick up the writing. Papyrus is nonabsorbent, so the ink is slightly raised on the surface.

Mocella inquired at the National Library in Naples about the possibility of putting a scroll inside the synchrotron at Grenoble, and was told that it was out of the question. On learning of the scrolls at the Institut de France, he contacted Delattre in the summer of 2013, and secured his help in getting the institute to agree to lend one scroll and fragments of one of the damaged ones. Late that fall, Delattre brought two fragments and a complete scroll, packed in a cylindrical foam case that Seales had designed for the CT scans, to Grenoble on the T.G.V. train from Paris. Seales, however, would not be travelling there with him.



"My next big project is brakes."

MAY 12, 2008

The E.S.R.F. is situated in an expansive research park, just above the confluence of two rivers, the Isère and the Drac, at the northern end of Grenoble, the small, mountain-ringed city that was the site of the 1968 Winter Olympics. The accelerator there is a ring, a kilometre in circumference. It is densely packed with "hutches," where the experiments take place. Inside each hutch is an experiment room, where the beam collides with the sample, and a control room, where the scientists monitor the resulting scan on computers. The whole accelerator is enclosed in its own building, with grounds surrounding it and a guesthouse for visiting scientists.

Delattre, as the conservator, was responsible for handling the fragments and the scroll, which had to be scanned individually. In the experiment room, he mounted each piece, one at a time, in a sample holder, where the beam would strike it. The two fragments were tilted; the scroll was placed vertically. Then he joined Mocella, Emmanuel Brun, a French physicist also with the E.S.R.F., and Ferrero in the control room and started the experiment. The sample was exposed to the beam. By turns, the beam passed through the two fragments and the scroll and its many layers, and struck the detector behind, which recorded the information about contrast densities. The beam is invisible, and exposure to it is dangerous; the researchers had to remain in the control room during the scans, which generally lasted for a few hours. The sample holder rapidly rotated the scroll and the fragments in microfractions of three hundred and sixty degrees as the beam flashed. Because the beam is so small, millions of exposures are needed to get a 3-D picture of a scroll. Although the letters are only two or three millimetres high, hundreds of scans are required to get enough information to make out a single letter.

The team waited nervously while the machines compiled the results. (Rendering the scans into images takes tremendous computer power.) On the second day, they began to see images. At first, the landscape looked bleak, barren of readable surfaces. The carbon in the crosshatched papyrus fibres (the sheets were made by pressing two pieces of papyrus together) stood out as dark streaks. But later that day the team had "an impression," as Mocella puts it, of letters in one spot on the intact scroll, on an exposed edge about two-thirds of the way in. After two weeks of work, Delattre confirmed the impression. Altogether, the team found writing scattered throughout the scroll, and in one fragment they found a series of letters next to each other—pi, iota, pi, tau, omicron, iota—which means "would fall."

The article in which the team reported their findings, “Revealing Letters in Rolled Herculaneum Papyri by X-Ray Phase-Contrast Imaging,” published in *Nature Communications*, in January, 2015, brought almost as much attention to the scrolls as had Paderni’s letter to Mead. As proof that the concept of virtual unwrapping could work, it was a milestone. “It’s the first hope of real progress we’ve had in a long time,” David Sider, of N.Y.U., told me. But, so far, the rate at which the team is reading the text makes Piaggio’s machine seem positively to hum by comparison.

More than three-quarters of the Villa dei Papiri has never been excavated at all. It wasn’t until the nineteen-nineties that archeologists realized that there are two lower floors—a vast potential warehouse of artistic treasures, awaiting discovery. A dream held by papyrologists and amateur Herculaneum enthusiasts alike is that the Bourbon tunnellers did not find the main library, that they found only an antechamber containing Philodemus’ works. The mother lode of missing masterpieces may still be there somewhere, tantalizingly close.

Mocella accompanied me on my visit to the Villa dei Papiri. Giuseppe Farella, who works for the Soprintendenza, the regional archeological agency, which oversees the site, took us inside the locked gates and led us into some of the old tunnels made by the Bourbon *cavamonti* in the seventeen-fifties. We used the lights on our phones to guide us through a smooth, low passageway. An occasional face emerged from the faint wall frescoes. Then we came to the end.

“Just beyond is the library,” Farella assured us, the room where Philodemus’ books were found. Presumably, the main library, if one exists, would be near that, within easy reach.

But for the foreseeable future there will be no more excavations of the villa or the town. Politically, the age of excavation ended in the nineties. Leslie Rainer, a wall-painting conservator and a senior project specialist with the Getty Conservation Institute, who met me in the Casa del Bicentenario, one of the best-preserved structures in Herculaneum, said, “I am not sure excavations will ever be opened again. Not in our lifetime.” She pointed to the paintings on the walls, which the G.C.I.’s team is in the process of recording digitally. The colors, originally vibrant yellows, had turned red as a result of the heat from the volcano’s eruption. Since being uncovered, the painted architectural details have been deteriorating—the paint is flaking and powdering from exposure to the fluctuating temperature and humidity. Rainer’s project analyzes how this happens.

“Would it be possible to get baked beans on toast? I’m not British—I’m just crazy.”

NOVEMBER 26, 2001

Richard Janko, of the University of Michigan, argues that books are a special case, archeologically, and should be excavated regardless. “Books are a different kind of artifact,” he said. “You can gain knowledge of a whole way of life through a single book. They are designed to carry information across the centuries.” If we wait until the volcano erupts again, he warns, they could be lost forever. Vesuvius, which has erupted scores of times since A.D. 79 and is still one of the most dangerous volcanoes on earth, has been quiet since 1944.

Brent Seales, denied the scientific glory of being the first to see inside the rolled scrolls, has been focussing on the software side of the problem. If large portions of wrapped scrolls are ever going to be read virtually, the process will have to be automated. You’d need a scroll reader that skims along the surface of each successive fold, looking for characteristic shapes and densities of letters. Seales has been designing a prototype for such software, and he showed it to Delattre recently. “Impressive” was the Frenchman’s opinion. Janko thinks that “clearly the way forward from here is to combine the work Seales is doing with Mocella’s data.”

Such a convergence seemed poised to occur this spring, when Seales, Delattre, and Mocella were set to meet in Grenoble, for another synchrotron session: the software engineer, the papyrologist, the physicist, and a whole week of beam time. (Seales still wasn’t part of the team, but he was coming anyway, to present his virtual-unwrapping software.) At the last minute, though, the team didn’t get the scroll. Only days before the experiment was set to begin, the Institut de France indicated that it could not grant Mocella’s request. No official reason was offered, but the recent publicity about the virtual unwrapping was thought to have caused the institute to reëvaluate the scrolls in terms of intellectual property. Controlling access to the scrolls has always been a form of power.

The institute’s decision was a blow to Delattre. When I saw him not long afterward, in the institute’s library, he still seemed shaken.

While the box containing Objet Un was open, I asked Delattre whether he thought the scroll would ever be virtually unwrapped. He considered the question while gazing at the black, shrivelled lump of carbon. On the one hand, it was just an old burned-up word turd left behind by a minor Greek poet and unoriginal thinker. But, on the other hand, it was an invisible stream through which knowledge and pleasure and advancement flowed—if only you could get the access.

“I do not expect this scroll will be read during my lifetime,” Delattre said, finally. He closed the lid of the small box with both hands, his shoulders slumped in defeat. ♦

John Seabrook has been a contributor to *The New Yorker* since 1989 and became a staff writer in 1993.