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The Herculaneum Papyri

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Abstract: This paper surveys the history of the Herculaneum papyri, as well as past, current and future research on the collection. Buried under the ashes of Vesuvius in the eruption of AD 79, the so-called Villa dei Papiri in Herculaneum contains the only library to survive intact from the Greco-Roman world. Soon after its discovery in 1752, it was identified as consisting mainly of works on Epicurean philosophy, especially by Philodemus of Gadara (ca. 110–35 BC). The charcoaled papyrus scrolls, inscribed with charcoal-based ink, present scholars with unique practical challenges. Early attempts to unroll them and read their contents yielded promising results but often resulted in serious damage to the material. Modern imaging techniques have significantly increased the legibility of extant fragments, and with the help of computerised tomography and machine learning it becomes increasingly possible to distinguish writing from background material in still rolled-up papyri. The Holy Grail of Herculaneum papyrology, namely to unroll and read the scrolls virtually, seems no longer out of grasp.

Keywords: Herculaneum, Villa dei Papiri, Herculaneum papyri, Epicureanism, Philodemus of Gadara, imaging

On 24 August AD 79, Mount Vesuvius erupted.[1] For two days, pumice, ash and pyroclastic flows pounded and destroyed surrounding towns and settlements. Pompeii, the most famous of these, has acquired the status in disaster narratives of an archetypical ground zero,[2] but there were many others, each with its own story to tell. Surely the most remarkable is the story at Herculaneum.

Pompeii lay to the southeast of Vesuvius, while Herculaneum lay to the west. On the first day, the wind blew towards Pompeii, so that it took the brunt of the initial fallout of pumice and ash. Both towns subsequently endured multiple pyroclastic flows, but owing to their different directions and distances from the volcanic core (7km in the case of Herculaneum,

[1] Recent discoveries have suggested a date later in the autumn, but the traditional date remains likelier; see Foss (2022).
[2] Hales and Paul (2011), especially Paul's essay therein.

Fig. 1: Reconstruction of the Villa of the Papyri, Herculaneum. Fondazione Cives–Museo Archeologico Virtuale Ercolano.

12 in the case of Pompeii) the effects were unequal (see Foss 2022: 151–71 for a detailed account of the sequence). In Herculaneum, the first flow of hot gas and volcanic materials was hot enough to kill all the inhabitants, but not dense enough to seriously damage the buildings. The second one during the night between the first and second days was denser, and did cause much damage, but nothing like the flow on the morning of the 25th which levelled Pompeii. By this time, Herculaneum was already buried, which partly explains why it is better preserved.

The first flow at Herculaneum was probably responsible for the extensive carbonisation there of organic material, while the second flow buried everything in a dense, anaerobic environment; this is the second reason for its better preservation. The absence of oxygen ensured that bacteria could not flourish, slowly to eat away at what was left. Consequently, there survive, far more than at Pompeii, such things as wooden construction materials (doors, windows, partitions, stairs, roofs etc.), furniture, tools and equipment (e.g. the huge screw press in a wool merchant's shop, unique in the Roman world), a boat and its tackle, textiles, foodstuffs and even the contents of sewers. And then there are the papyri, which

were found in the Villa consequently named after them.

Since antiquity it had been known that underneath the surrounds of Vesuvius ancient remains were to be found. Medieval punters sank shafts in the hope of finding precious artefacts; well-diggers made chance discoveries. The ancient theatre was found in this manner in 1709, and the Prince d'Elboeuf (Emanuele Maurizio di Lorena), commander of the Austrian cavalry in Naples, who was at the time building a residence in nearby Portici, expropriated it for the Austrian government and plundered its contents (Harris 2007: 26; Longo Auricchio 1997). Such a structure indicated a town, but it was not until the arrival of the Bourbon King of the Two Sicilies, Charles III, in 1738 that systematic exploration began. In 1750, a superb polychrome mosaic floor came to light at the bottom of a well; this turned out to be the circular foundation of a belvedere, which stood at the end of a promenade leading to a huge suburban villa on the edge of ancient Herculaneum. The total frontage was over 200 metres. In addition to the traditional atrium and peristyle of a Roman house, there was a grand peristyle set at right angles to the main house with a water feature in the middle longer than a modern Olympic pool (Fig. 2). As we know from excavation in the 1990s, there were also lower levels beneath the atrium quarter, a sizeable extension to the southeast, and a seafront pavilion. Such a building would have been affordable only by a wealthy Roman aristocrat.[3]

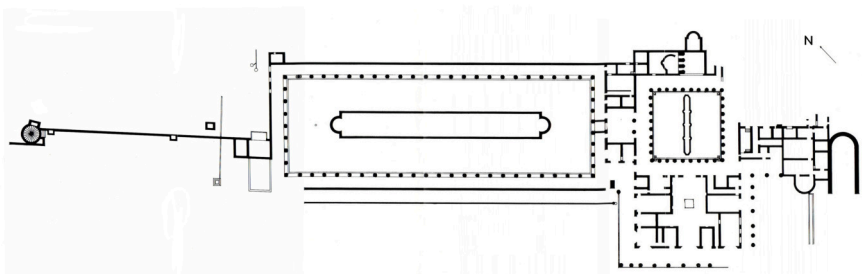

Fig. 2: Plan of the Villa of the Papyri. Prof. Mantha Zarmakoupi, University of Pennsylvania.

The Bourbon excavation was carried out in a maze of underground tunnels constructed by the Swiss army engineer Karl Weber. The conditions were appalling: with their path lit only by smoky torches the men hacked their way through rock-hard volcanic material, battling poisonous gases and underground water. Fortunately for us, Weber had the foresight and the tenacity to map the plan of the Villa in meticulous detail, cataloguing the findspots

[3] Or a modern oil baron; J. Paul Getty designed his villa in Pacific Palisades CA, now the Getty Museum, after the Villa of the Papyri as known from Weber's plan. For accounts of the early discoveries see e.g. Longo Auricchio, Indelli, et al. (2020: 15–38), translated in McOsker (forthcoming); Sider (2005: 16–23); Fleischer (2022: 11–18); Wallace-Hadrill (2011: 41–56); Harris (2007: 25–61).

of his discoveries. At times he incurred the wrath of his employer, who was impatient for treasures, but in due course these were delivered in abundance. The haul included over sixty bronze and twenty-four marble statues, and many artefacts in silver and gold (Wallace-Hadrill 2011: 114).

In 1752 Weber's team began to encounter papyri. His diary dates the first encounter to 22 October and does not support the oft-repeated story that the workmen first thought the twisted black lumps to be charcoal, even using them as such, until one cracked open and revealed writing.[4] Weber had found the only library to survive intact from the Greco-Roman world. Some 1800 whole and broken parts of rolls were catalogued, representing perhaps 800 original books.

As word spread, excitement mounted that long-lost masterpieces of ancient literature would be re-discovered, or perhaps a pristine copy of a surviving work—the lost books of Livy or Polybius! new plays by Sophocles! or even an autograph copy of Virgil's *Aeneid*! As the rolls started to be prised open, however, disappointment rose in direct proportion to the high expectations, as one text after another proved to be Epicurean Greek philosophy, and mostly by an obscure representative of the school, one Philodemus of Gadara (now Um Qeis, in Jordan), who was active in the first century BC and had hitherto been known mainly for some epigrams preserved in the Greek anthology. Dry stuff to most tastes, and not the most scintillating of writers, at least not in his prose.[5]

We will come to the books and their significance at the end of the paper, but first some words about the Villa and its library to contextualise the find. Philodemus is beyond reasonable doubt the anonymous Epicurean mentioned in passing by Cicero in his attack on Lucius Calpurnius Piso Caesoninus (*In Pisonem* 68–72) as a writer of erotic verse and philosophy. Cicero clearly held him in some esteem, as we know from his unqualified praise in *On the Ends of Good and Evil* (*De finibus bonorum et malorum* 2.119). Philodemus addressed one of his surviving epigrams to Piso (*The Greek Anthology* 11.44) and dedicated to him his treatise *On the Good King According to Homer*. Horace and other Roman poets were influenced by Philodemus, both stylistically and philosophically; Virgil's *Aeneid*, for instance, offers an extended meditation on anger, which is the subject of one of the philosopher's works.[6] Virgil, along with Plotius Tucca, Varius Rufus and Quintilius Varus, is actually addressed in Philodemus' *On Flattery.* These writers are known to have spent time in the Bay of Naples area studying Epicureanism; Philodemus' friend Siro was Virgil's teacher there.[7] Horace,

[4] Pannuti (1983: 313), from the diary: '...y cinco rollos consumidos, que, segun pareze, eran escrituras antiguas, hechas en la corteza de arbol, ú otra materia, las quales, con otras muchas, q.e se han observado deschechas, estavan conservadas en el estipo citado arriva'. See Fig. 6 (below) for a typical intact roll.

[5] The poems are different: see Gow and Page (1968, ii: 372–5) and Sider (1997). There are thirty-four genuine epigrams, two more of doubtful authenticity and two spurious.

[6] For these connections, see Armstrong, Fish, et al. (2004); Sider (1997: 12–24).

[7] Virgil, *Catalepton* 5, 8; Servius on Virgil, *Eclogue* 6.13; Donatus auctus, *Life of Virgil* 79 Diehl. See Gigante (1990).

an Epicurean down to the ground, mentions Philodemus at *Satire* 1.2.121. He also dedicated his *Art of Poetry* to members of the Piso family.

We know, therefore, that Philodemus had intimate connections with Piso, a very distinguished member of the Roman ruling class (and father-in-law of Julius Caesar). We also know that Philodemus had intimate connections with writers sympathetic to Epicureanism who spent much time in Campania. The library of the Villa contains a great many works by Philodemus—not only finished copies, but duplicate copies and drafts. It contains works by writers he criticises, and of course many books by the master Epicurus and other members of the School. It looks very much like Philodemus' personal working library, or at least the philosophical part of it. Now we do not know if Piso owned a villa in this area, but our villa must have belonged to someone like him, and given the links to Philodemus he remains much the most probable owner; if not he, a member of his family. Piso died sometime after 43 BC, Philodemus in the mid-30s.[8] The earliest wall paintings, according to one assessment, date to the 30s, indicating that the complex was begun not much before that (Guidobaldi and Esposito 2010: 57), though some scholars do not rule out a start as early as 60 BC (De Simone and Ruffo 2003: 307). If the later date is correct, then Philodemus spent only the last few years of his life here with his books, though his association with Piso dated back decades before. One can of course imagine other scenarios, for instance that the library was moved by the family from Rome to this new country dwelling after the philosopher's death, or even that some fan of Epicurus bought the library from the Pisones and installed it there. Certainty eludes us, but the simplest hypothesis—the Villa was built by Piso Caesoninus, and lived in by Philodemus—remains most favoured.[9]

The collection continued to be augmented, though not extensively, in following years, as the handwriting of the Latin papyri in particular indicates (Del Mastro 2005b; 2010: 64–5); apart from that criterion, we also have a papyrus containing lines from a poem about the Battle of Actium (31 BC), and another containing the end of Seneca the Elder's (d. AD 39/40) *History of Rome from the Start of the Civil Wars*, which was finished after his death by his son.[10] The oldest papyri date to the third century BC; it has recently been shown that a copy of Epicurus' *On Time* dates to the first half of that century, which means it could have been written during the author's lifetime (Lavorante 2022; see Fleischer 2019 for other third-century papyri). The majority of the papyri are, however, Philodemean, from the first century BC. Philodemus presumably brought his books, including the older ones, with him to Rome, where he continued to build up the collection and, of course, add his own writings.

[8] On *Inscr. Ital.* X.1.65, X.1.81 and X.1.708, which mention a L. Calpurnius Piso Caesoninus and which Frischer (1991: 55–56, 115–25) used to argue that Piso lived until after 33 BC, see Sider (1997: 11 n.32) (agreeing with those who think they refer to a younger Piso).

[9] For the complete list of suggestions, see Capasso (2010). L. Calpurnius Piso Pontifex, Caesoninus' son, is gaining favour. See also Houston (2014: 101–5) for some reasons to doubt the standard narrative.

[10] *P.Herc.* 817 (Actium): see Lucarini (2021); *P.Herc.* 1067 (Seneca): see Piano (2017, 2020).

If that much is clear, much else remains puzzling about this library. Philodemus was a poet as well as a philosopher; one would expect him to have the standard Greek classics in his collection. None of these has so far been found. Richard Janko has recently argued that one of the Herculaneum papyri preserved in Paris (six were gifted to Napoleon by Ferdinand IV of Naples in 1802) is an historical work on the warring successors of Alexander the Great—so far the only non-philosophical Greek text identified (Janko 2023). Since the Villa belonged to a Roman aristocrat, one would also expect there to be an extensive Latin library, such as Cicero speaks of often in his letters in connection with his own (many) country homes and those of friends. 124 Latin papyri have so far been catalogued (Piano 2020: 33). This is a small proportion of the total. In other words, the library as it stands is quite lopsided, and not at all what one would expect; the some 600 fragments (representing perhaps 300 scrolls) that remain to be unrolled might change the picture, but probably not radically. The question naturally arises, is this all there was in the Villa to begin with, and if not, where are the rest of the books?

Weber carefully noted where he found the papyri, and how they were arranged. The bulk were found in a single room, on shelves, clearly a storage room. Others were found in or near the *tablinum* (the space connecting the small and grand peristyles), in carrying cases, in a cabinet, or lying on the ground (Fig. 3).

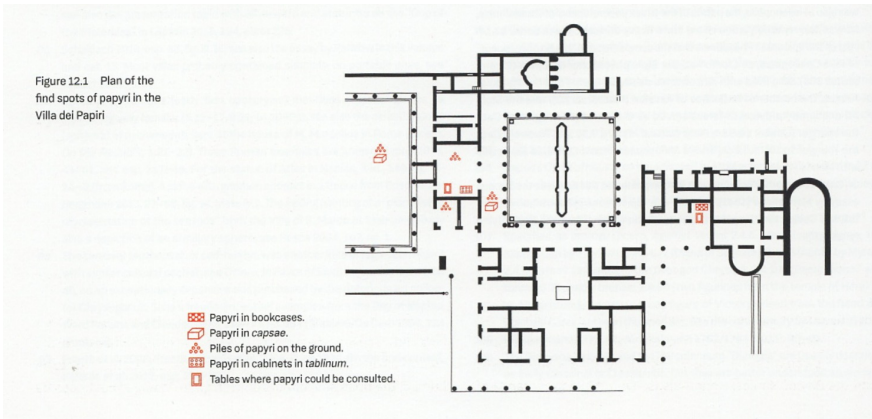

Fig. 3: Findspots of Papyri. J. Paul Getty Museum (Pacific Palisades CA), *Buried by Vesuvius: The Villa dei Papiri at Herculaneum*, p. 47.

Because of this disposition it has often been suggested that the library was in the course of being removed when the catastrophe struck; the Epicurean books (the least valued, a cynic might remark) were at the end of the queue, and did not make it out.[11] That is, we

[11] On the contrary, Del Mastro (2010) suggests that in the first century AD a flurry of re-copying and restoring older

have found all that there is to find. A strong argument against this hypothesis is that there was hardly enough time to arrange an orderly evacuation. The occupants had less than twenty-four hours' notice between the first fallout at Pompeii and the first lethal devastation at Herculaneum; they would not have known what the earthquakes of preceding days presaged, or that the Villa would be buried beyond recovery. After an explosive eruption like that most people would grab what they could and flee. That is exactly what the inhabitants of the main town tried to do, as we know from the skeletal remains on the ancient shoreline. Various scenarios can be imagined to explain why books were found thus disposed, for instance that building works or a reorganisation of the library were underway. The identification of at least some non-philosophical papyri, however few in number, shows that the library was not confined to this one subject. So where in the Villa might the other books be? Weber failed to reach the southeastern part, where there was another complex of rooms; this unexcavated portion is a strong candidate for the location of further papyri. There are also the lower levels found in the 1990s excavation; these have been only partly explored, but the two rooms investigated on the first level below the atrium were beautifully finished, which means that this first level at least was not merely a service area.

Further excavation is the only way to find out if the rest of the library is there, but this is not the place to discuss the pros and cons of such an undertaking. The southwestern part of the atrium quarter was exposed in the 1990s. To achieve this an enormous trench was sunk from the main site down to the Villa, exposing other buildings along the way (Figs 4, 5). The excavation was funded directly by the Ministry in Rome, and when the first tranche of money ran out a new regime declined to continue the project.[12] Since then, archaeologists have concentrated on stabilisation and conservation of the existing excavation. Many obstacles lie in the path of continuation, not least the fact that above the atrium lie the historic town hall and its garden, and various other buildings. The cost would be staggering, not only of excavating but of conserving what is excavated, and the many stakeholders would need to be persuaded of the benefits. Yet the Villa, and the library it possibly contains, are of unique historical importance. The debate will continue.

The discovery of these papyri marks the beginning of modern papyrology, throughout whose history they have played a central role owing to the exceptional challenges they present the editor. They can be as fragile as burnt newspaper. Even when the layers of a scroll are separated one may find only black ink on charred papyrus, with little visible to the naked eye (Fig. 6). A quick outline of the history of decipherment will bring out the inherent difficulties and lead us to the latest exciting innovations, which have implications

Epicurean texts indicates an ongoing interest in the subject.

[12] De Simone (2010); Camardo (2019). A helpful panorama of the site is available at https://tinyurl.com/VdPPanorama (accessed 9 September 2025).

Fig. 4: The excavation trench (Villa of the Papyri at the far end; see Fig. 5). Photograph by Robert L. Fowler. Reproduced by permission of the Ministero della Cultura / Parco Archeologico di Ercolano. Further reproduction or duplication in any medium or form is prohibited.

Fig. 5: The exposed atrium quarter showing lower levels. Photograph by Prof. Mantha Zarmakoupi, University of Pennsylvania, reproduced by permission of the Ministero della Cultura / Parco Archeologico di Ercolano. Further reproduction or duplication in any medium or form is prohibited.

far beyond the world of Herculaneum papyri.[13]

Early attempts to get at the contents were disastrous. Scrolls were cut in half lengthwise, producing two tall semi-cylinders. On each side of the knife much material was destroyed. Unbelievably, the narrow, innermost layers were sometimes scooped out until more easily read parts were reached. Fortunately, it was soon realised that the core, dubbed the 'marrow' (*midollo*), was often soft and pliable enough to be unrolled relatively intact, given sufficient care. Cuts were then made only as far as the outer edge of the *midollo*, or at least where that tractable part was thought to begin. So now one had three parts: the rolled-up *midollo* and two half-cylindrical outer casings, dubbed the 'barks' (*scorze*). The *midolli* were unrolled with the aid of an ingenious machine designed by Father Antonio Piaggio (1713–1796), one example of which can be seen in the Museo Archeologico Nazionale di Napoli (Fig. 7). Finding and gently lifting the outer edge of a *midollo*, he glued onto it a piece of

[13] Further accounts in varying detail of the history are available in Janko (2003: 15–39); Sider (2005: 46–59); Delattre (2007, lvi–cvii); Longo Auricchio, Indelli, et al. (2020: 53–68), translated in McOsker (forthcoming); Fleischer (2022).

Fig. 6: A charred piece of papyrus. MS. Gr. class. b. 1 (P)/5. Bodleian Library, University of Oxford (Digital Bodleian). Creative Commons licence CC-BY-NC 4.0.

animal membrane (goldbeater's skin), which was then connected by threads to a rod above. As the threads were tightened the scroll was lifted and began to unroll under its own weight at a rate of about an inch a day, assisted by gentle prodding with a needle or scalpel and glue where needed.

The innermost layer of the *scorze* could often be read. Draughtsmen who knew no Greek were hired to transcribe them, so that they would copy only what they saw, without being tempted to write what they thought the Greek should be, or to fill in lacunae. Once a layer was transcribed, it was scraped off to reveal the next layer, and so on until the last or an illegible layer was reached. For these layers, which were destroyed in the process, we are today entirely dependent on their *disegni* (drawings); the last layer might still survive. *Disegni* were also made of the *midolli*, and they too can be valuable in various ways, most obviously when the *midolli*, even if surviving, have since deteriorated (Fig. 8).

The *scorze* were sometimes broken into two or even three parts to make them more manageable. Very often the two *scorze*, their parts (if broken), and the *midollo* became separated and were assigned different catalogue numbers, making it very difficult to reunite parts that belonged together. Haphazard treatment of the rolls in the early days made matters worse. For instance, when Napoleon invaded in 1798 the Neapolitan court fled to Sicily and took the whole collection with them in crates: more opportunities for breaking, jumbling, loss. Painstaking work in the archives, analysis of the handwriting and bibliological characteristics of the papyri, consideration of the contents, and hunting for physical joins, enable modern scholars, with patience and luck, to find the *disegni*, *scorze* and *midollo* (if extant) that belong together in the original book. The archives in particular are a bewildering labyrinth of catalogues, correspondence and records of various kinds, often partial, contradictory, following different systems and liable to error.[14]

Even when the papyri are reunited the work has hardly begun, for the fragments of each one must be assigned their rightful place in the original scroll. Transcribing the contents is a necessary part of the process (on which more in a moment), but since all the fragments together usually amount to only a portion of the original book, the precise sequence of the argument may remain elusive. Content is only one indicator among others. Vertical creases can reveal the circumference of the scroll at any given point; since the distance between creases gradually decreases from outside to inside, a fragment from a part where the circumference is less must come from closer to the end of the scroll than one whose measurement is greater. (So far no scroll has been discovered where an inconsiderate reader failed to roll it back up after unrolling and reading it, which would of course leave the end

[14] Any good modern edition will reveal the complexities, but for particularly jaw-dropping examples see Nicolardi (2018: 52–162) and Janko (2020: 3–48). In the first case, papyri with fourteen different catalogue numbers are involved.

Fig. 7: Piaggio's macchine. Naples, Biblioteca Nazionale "Vittorio Emmanuele III," Officina dei Papiri Ercolanesi 334.

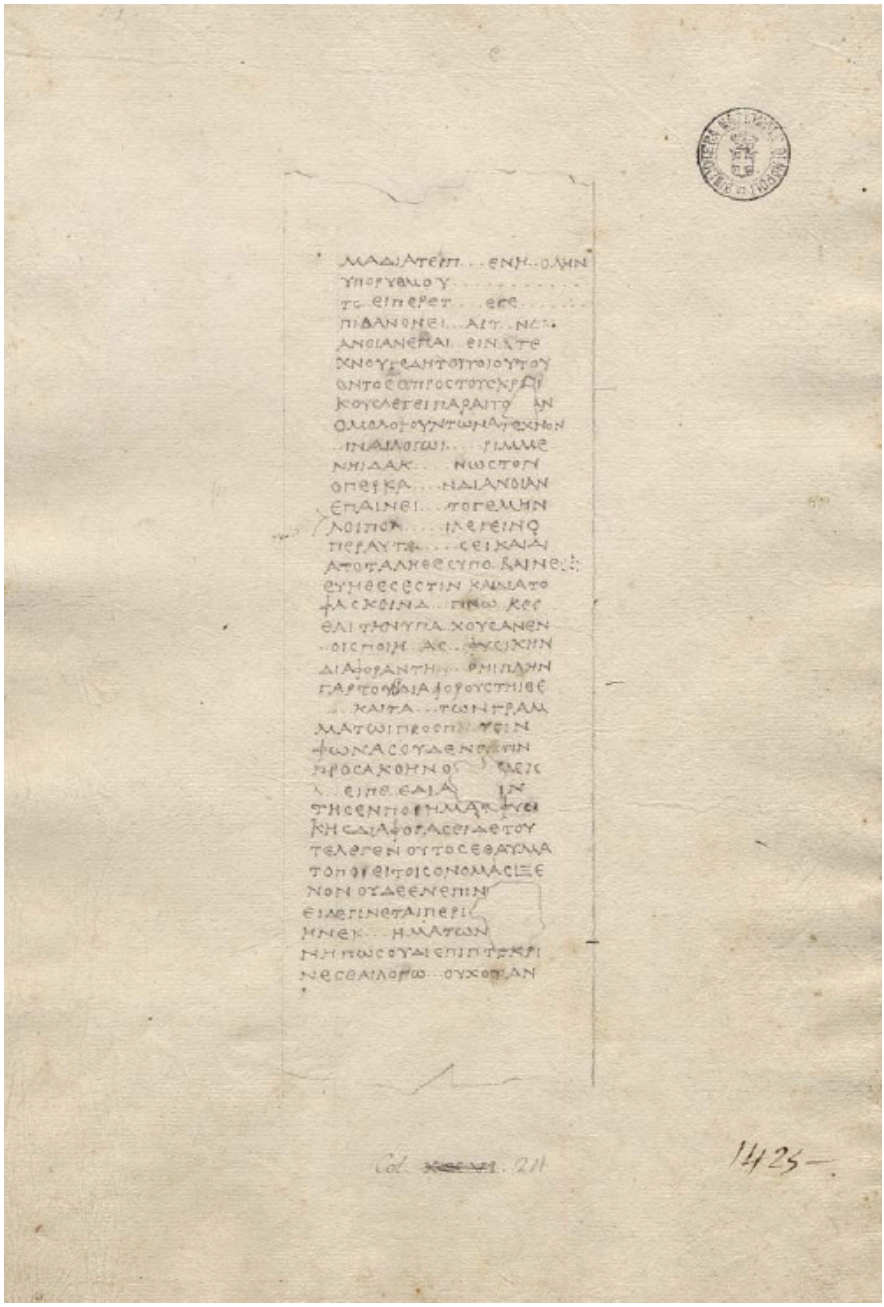

Fig. 8: *Disegno* of Herculaneum Papyrus 1425, column 24: Philodemus *On Poems* Book 5. Public domain: https://commons.wikimedia.org/wiki/File:Herculaneum_papyrus_1425.png.

of the book at the outside.) The order in which the layers were transcribed can often be determined, although until the 1980s it was thought that 'fragments 1, 2, 3' and so on in the old catalogue entry of a single papyrus designated their order in the original book, whereas in fact the original order was usually 3, 2, 1, since the transcribing and scraping away, as we saw, proceeded from inside to outside.[15] Matters are further complicated by the frequent phenomenon of *sovrapposti* and *sottoposti*, in which fragments from the layer on top (that is, closer to the end) or underneath (closer to the beginning) became detached from their own place and stuck to the layer being transcribed. These need to be identified and re-assigned to their proper place. The height and width of columns, the space between them, the number of lines per column and number of letters per line, total line numbers in the book so far as sometimes noted in the margin, and other statistics need to be taken into account. The length of the scroll and the total number of columns may be possible to calculate. Scholars construct physical or digital models of the original (which may reach a length of twenty metres or more) in order to determine possibilities for the placement of fragments and check the plausibility of their reconstruction. There are other complications, but what has been said gives an idea of the phenomenally difficult process of solving this multi-dimensional jigsaw puzzle, with many or most of the pieces and the overall design missing.

The challenges of transcribing are no less daunting. A good microscope is indispensable, but since 1999 first multispectral imaging (MSI) and then shortwave infrared hyperspectral imaging (HSI) have spectacularly supplemented what can be seen in visible light. Both depend on finding a frequency in the infrared range at which the ink reflects back more clearly than the underlying papyrus. Undifferentiated black surfaces suddenly become legible; the difference is stunning, and by definition the readings cannot be checked in the original by the human eye. HSI on the whole yields more and better results than MSI, but not always. One needs both (and there are still times when old-fashioned visual inspection is required). Another imaging technique is reflectance transformation imaging (RTI), which involves taking multiple photographs of the papyrus with light coming in from different angles. These can then be digitally combined and manipulated in various ways. The method brings out all the subtle ripples and irregularities on the surface, eliminating the effects of shadows, resolving doubts about the presence of ink and revealing *sovrapposti* and *sottoposti*, among other things. Recently a project undertaken by Brent Seales and a team from the University of Kentucky has been combining new images of all the Herculaneum papyri and the data from previous imaging into a single, manipulable database, bringing yet more enhancements in legibility (for an example, see https://educelab.gitlab.io/dri-

[15] One has also to alternate between the *scorze*. There are, moreover, some instances where the order is right. The discovery was made independently by Daniel Delattre and Dirk Obbink (though Adolf Schober had anticipated it in 1923, in a work not published until 1988). See Schober (1988); Obbink (1996, vi, 37–53); Janko (2003: 18); Delattre (2007, cii–cvii).

voyager/, accessed 9 September 2025).

The same Kentucky team has been pursuing for some twenty years what can well be called the Holy Grail of Herculaneum papyrology: finding a way to read still rolled-up papyri without physical intervention and associated damage. The technique deploys X-ray-based micro-computed tomography (CT scanning, such as one undergoes in a hospital, but with a far more sophisticated scanner) to map the interior structure of a roll. In a nutshell, thousands of shots are taken at right angles to the long axis of the scroll, like salami slices. The different densities of material within—papyrus, pumice and other materials from the eruption, dirt, ink, the air between layers—are registered by the scan and analysed to identify the contiguous layers, a process known as 'segmentation' (Figs 9, 10).

Fig. 9: Scanning a scroll. EduceLab, University of Kentucky.

The compressed, mangled and twisted state of the Herculaneum scrolls makes their segmentation exceptionally challenging. An additional problem is this: in modern inks, and ink from later centuries in antiquity, a metallic element such as iron gall or lead is often present. If so, the density of the ink is much greater than that of the papyrus and is easily detected. Such was the case when a small fragment of a leather scroll (about 7cm by 1cm), originally found in 1970 by archaeologists in an ancient synagogue in En Gedi, Israel, was scanned and virtually unwrapped in 2015. Dating to the third or fourth century AD, it proved to contain portions of the first two chapters of Leviticus (see https://www2.cs.uky.edu/dri/the-scroll-from-en-gedi/, accessed 9 September 2025). The efficacy of the method was spectacularly proved. The problem with the Herculaneum papyri, however, is that the ink contains no metal, except sometimes by accident; it was made with

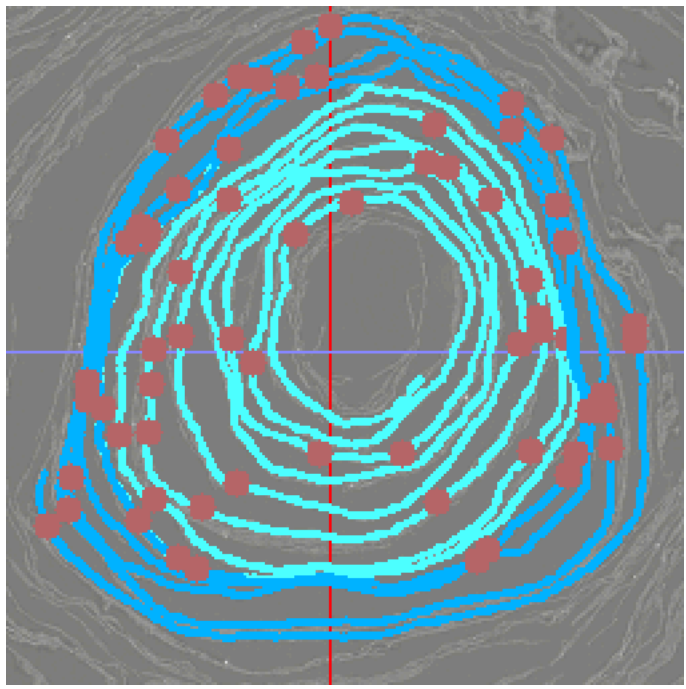

Fig. 10: Segmentation. Vesuvius Challenge.

ground charcoal, water and a bonding agent such as gum of arabic. The density differs little from that of the underlying papyrus.

At this point, machine learning enters the picture. Using modern mock-ups as well as a tiny fragment of Herculaneum papyrus on which the letter sigma was clearly written, the team, knowing ahead of time what a perfect result would look like, experimented with different settings in the scanning. The computer could be told where it had gone wrong and gradually improve its algorithms. Good progress was made in this way, but not enough, and much more data was needed, such as a complete roll could provide. Here the Institut de France stepped up, and agreed to have one of its papyri, *P.Herc.Paris.* 4, transported to the synchrotron particle accelerator at the Diamond Light Source facility in Didcot, near Oxford.[16]

The Kentucky équipe continued to make progress with the data obtained from this

[16] The scroll had initially been scanned in Paris in 2009, producing a basic map of the interior, and again in 2013 at the European Synchrotron Radiation Facility in Grenoble, attempting to use phase contrasts in the X-rays to find the ink; this did not produce the results hoped for. See Nicolardi, Parsons, et al. (2024: 6).

scan, but a step-change was achieved with the advent of the 'Vesuvius Challenge' (www.scrollprize.org). Silicon Valley IT entrepreneur and former CEO of GitHub, Nat Friedman, learned of the project, and suggested to Seales that a world-wide competition be held, inviting entrants to build on his results. A million dollars were put up as prize money. Intermediate prizes were offered along the way for improving specific aspects of the technique, and at each stage the winning code was published, so that all the entrants (over 1200 teams!) could start on the next leg from a common baseline, learning from each other. In October of 2023 a 'First Letters Prize' of $40,000 was awarded to Luke Farritor, an undergraduate at the University of Nebraska, who was the first to identify at least 10 letters in 4cm^2 of the papyrus. The word 'purple' was read, and the announcement caught the attention of the world's press (Nicolardi, Parsons, et al. 2024). Purple dye was expensive in the ancient Mediterranean, a mark of high status; speculation suggested that the subject of the text was wealth. The next deadline was the end of 2023 for entries to the Grand Prize of $700,000, with a target of four passages of 140 characters each, with at least 85% of the letters recoverable. Farritor, Youssef Nader (a PhD student at the Freie Universität, Berlin, and First Letters runner-up) and Julian Schilliger (a software engineer working in Switzerland), joined together to win the Grand Prize by reading the middle parts of 15 columns, more than 2,000 characters (Fig. 11). The result was published by Nicolardi, Delattre, et al. (2024). When the target was set, nobody knew if it was realistic; in the end it was far exceeded.

Fig. 11: Vesuvius Challenge 2023 Grand Prize winning entry. Treatise on aesthetics. Vesuvius Challenge, Académie des Inscriptions et Belles Lettres, Institut de France, Paris.

An even more ambitious target was set for 2024, to read 90% of the four scrolls scanned. This was not in the end achieved, but significant improvements have been made in automating the segmentation, the necessary prelude to joining up the traces of ink. In 2023 the segmentation was done manually, as it were, that is the data were interpreted by a human analyst, which would take hundreds of years of analysts' time (and prohibitive costs), if it were done for all of the rolls. Early in 2025 one of the rolls in the Bodleian Library produced exciting results, much touted in the press (e.g. https://www.bbc.com/news/articles/c5yvrq7dyg6o, accessed 9 September 2025), who seemed to think this was the first time such a scan had been done. Lots of ink appeared, but few legible words; however, the exciting thing for those in the project was that this much ink was close to being legible without the intervention of AI.

X-ray computed tomography is not in itself new to the world, but these refinements using artificial intelligence have great potential to improve its usefulness in both humanities and sciences by mapping the interiors of matter, including the human body, in ever more complexity and accuracy. For Herculaneum, the ultimate goal is to scan the hundreds of remaining scrolls. To do this, some engineering genius will need to design a portable scanner. At the moment, the costs and risks of transporting everything to a synchrotron particle accelerator are prohibitive. A portable scanner would have seemed a preposterous idea not long ago, but so would the rest of this story.

The subject of *P.Herc.Paris.* 4 turned out to be what causes pleasure or pain, and the effect of mixtures (e.g. of scarce and abundant elements in food). Sound (music), taste (foods; there is a mention of capers) and sight (purple!) are mentioned. Not enough has been deciphered to determine exactly what the argument is; as this is the end of the scroll, it is possible that topics are being outlined for the succeeding scroll, which the closing words lead us to expect. The author could be Philodemus, but there is not enough text to be sure yet. At all events, the subjects of sense perception and pleasure are emphatically Epicurean, for whom knowledge is derived from the senses, and for whom pleasure, properly understood, is the highest good.

So we come to the contents of the many scrolls read to date.[17] Unsurprisingly, Epicurus' foundational work, *On Nature*, is well represented, sometimes in multiple copies; ten of the original thirty-seven books have been identified (and Philodemus quotes from three others). Another work of his, *Echelaus*, is identified by its end-title; it is otherwise unknown, and its contents remain mysterious. Books by many of his disciples are also found: Metrodorus, Polyaenus, Colotes, Polystratus, Carneiscus, Zeno of Sidon, Demetrius Laco, writing treatises on physics, ethics, geometry, aesthetics and the history of philosophy. A prominent Stoic, Chrysippus, is represented in fragments of his works *On Foresight, On Logical Problems,* and *On the Elements [of Discourse] and Utterances.*[18] Of Latin papyri, only the two mentioned above, on the Battle of Actium and Seneca's Roman history, can be certainly identified; majority opinion now rejects the presence in the library of works by Ennius, Caecilius Statius and Lucretius (see Capasso 2011; Longo Auricchio, Indelli, et al. 2020: 79).

Then there is Philodemus, who accounts for the majority (approximately 60%) of the titles so far identified. His *Index of Philosophers* in at least ten books, a history of philosophy chro-

[17] Attributions and especially titles are not always certain; variants will be found according to which authority one consults (the *P.Herc.* number(s) provide a firm reference point, however). For overviews see Fleischer (2022: 26–27); Houston (2014: 90–98, 280–86); Henry (2013). For discussions, see Sider (2005: 60–95); Delattre (2007, xxii–lii); Longo Auricchio, Indelli, et al. (2020: 137–79), translated in McOsker (forthcoming).

[18] The last is *P.Herc.* 1380: Del Mastro (2005a) and Indelli and Longo Auricchio (2019: 189). Del Mastro read the end-title as [Πε]ρὶ τῶν [c]τοιχείων [τ]ῶν λεγομένων, which could be an abbreviated version of a work in Diogenes Laertius' list (7.192), Περὶ τῶν στοιχείων τοῦ λόγου καὶ τῶν λεγομένων, which I have translated above.

nologically organised by principal representatives of each school, is of great significance for the doxography and dating of these thinkers. The book on Plato and his successors in the Academy has recently been edited in a magisterial edition by Kilian Fleischer, which may also be consulted for the *status quaestionis* on many aspects of Herculaneum papyrology (Fleischer 2023; for a short, accessible introduction, see Fleischer 2022). The Epicureans occupied one book therein; three other, separate works were devoted to Epicurus and Epicureans, and one other book to Stoics. There are many works on ethical topics (flattery, slander, pride, anger, frank speech, conversation, gratitude, wealth, the proper attitude to death, managing your household, what to choose and what to avoid, and others) and *On the Good King According to Homer*, addressed to Piso, stressing the ethical qualities of a leader. Theology is represented by works *On the Gods, On Foresight* and *On Piety*; logic and epistemology in *On Methods of Inference* (or *On Phenomena and Inferences*, based on Zeno's lectures). Aesthetics are especially well represented: *On Rhetoric* best of all, in at least eight books; *On Music* in four books (Book 4 survives); and *On Poems* in five.[19] An absence from this list, puzzling in an Epicurean, is physics.

The significance of this library is hard to overstate. For students of the history of philosophy it is a treasure-trove. Except for Epicurus, *On Nature*, all these titles were previously unknown. The centuries between Aristotle and Cicero are a kind of Dark Age for us; no philosophical treatises survive. These papyri, fragmentary and desperately difficult though they are, have dramatically increased our knowledge. Each new edition brings major insights (which are often re-editions, transformed by modern imaging techniques).

What is true of philosophy is true of other fields as well. We knew very little about Hellenistic aesthetic and literary criticism before the papyri. They have begun to fill in this missing background to the artistic effulgence of the late Republic and early Empire. The more study proceeds, the more we find intertexts between Philodemus and these writers, and learn more about their cultural and intellectual context (Armstrong, Fish, et al. 2004). We learn not only from what Philodemus wrote himself, but from his quotations, often extensive, of others. He refers to dozens of authors, enabling us in some cases to restore to the world the outlines of their work (see Delattre 1996 for a list of works and authors quoted). For instance, two previously unknown Hellenistic critics attacked by Philodemus, Heracleodorus and Pausimachus, have been resurrected from *On Poems* 1 by Richard Janko, amounting to some 7,000 words for the former and 9,000 for the latter (Janko 2020: 507–99). The same scholar took Philodemus as a starting-point to re-edit the fragments of Aristotle's *On Poets*; although not all the new fragments come from Philodemus, Janko's edition quadruples the number of those previously known (Janko 2011: 317–539). It is also thanks to Philodemus that we now know about the critics Crates of Mallos, Megaclides of Athens, Ne-

[19] In these writings Philodemus also refers to four other works of his, which have so far not turned up among the papyri: *On Marriage*, *On Praise*, *On Beauty* and *On Diction*.

optolemus of Parion and Andromenides. The great second-century scholar Apollodorus of Athens wrote a large work *On the Gods*, which we can now see was a source, directly and/or indirectly, for Philodemus in his *On Piety* (Henrichs 1975). Through Apollodorus and other intermediaries Philodemus quotes many fragments of early poets and mythographers, whose views he will go on to refute; these have augmented modern editions of the authors in question. Apollodorus' influential *Chronicle*, dating events from the Fall of Troy (1184/83 on his reckoning) down to his own day, was originally written in iambic trimeters; modern editions of the work mix these together with later prose paraphrases, which can be misleading. 87 of the 109 original verses are preserved in Philodemus' *Index of Academicians*, many of them now read for the first time, and all of them better read by Fleischer, who has published all 109 as a parergon to his edition of the *Index*, with full commentary (Fleischer 2020). Consequently, the transmission and nature of this fundamental work are much better understood.

Much has been learned, and much remains to be learned. The Herculaneum papyri have been at the cutting-edge of papyrology since they were first discovered. The physical characteristics of these texts—construction, layout, scripts, paratexts and so on—have enriched our knowledge of ancient book production and consumption. The extraordinary difficulty of editing these papyri have forced papyrologists to fashion new tools to deal with them. The born-digital texts now coming out bring fresh challenges of transcription and interpretation. The fact that we have here an intact library, or part of one, from a wealthy Roman villa, affords insights into ancient literary culture. And, as we have just been discussing, the contents of these remarkable books have opened windows onto cultural landscapes we hardly knew existed. If the Holy Grail is finally grasped, and the hundreds of still rolled-up scrolls can be virtually unrolled—to say nothing of the library that many of us believe yet lies in the Villa—, there awaits for generations to come a paradise of discovery.[20]

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