Leonardo’s Intellectual Cosmos

Max Planck Institute for the History of Science

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz

Museo Galileo

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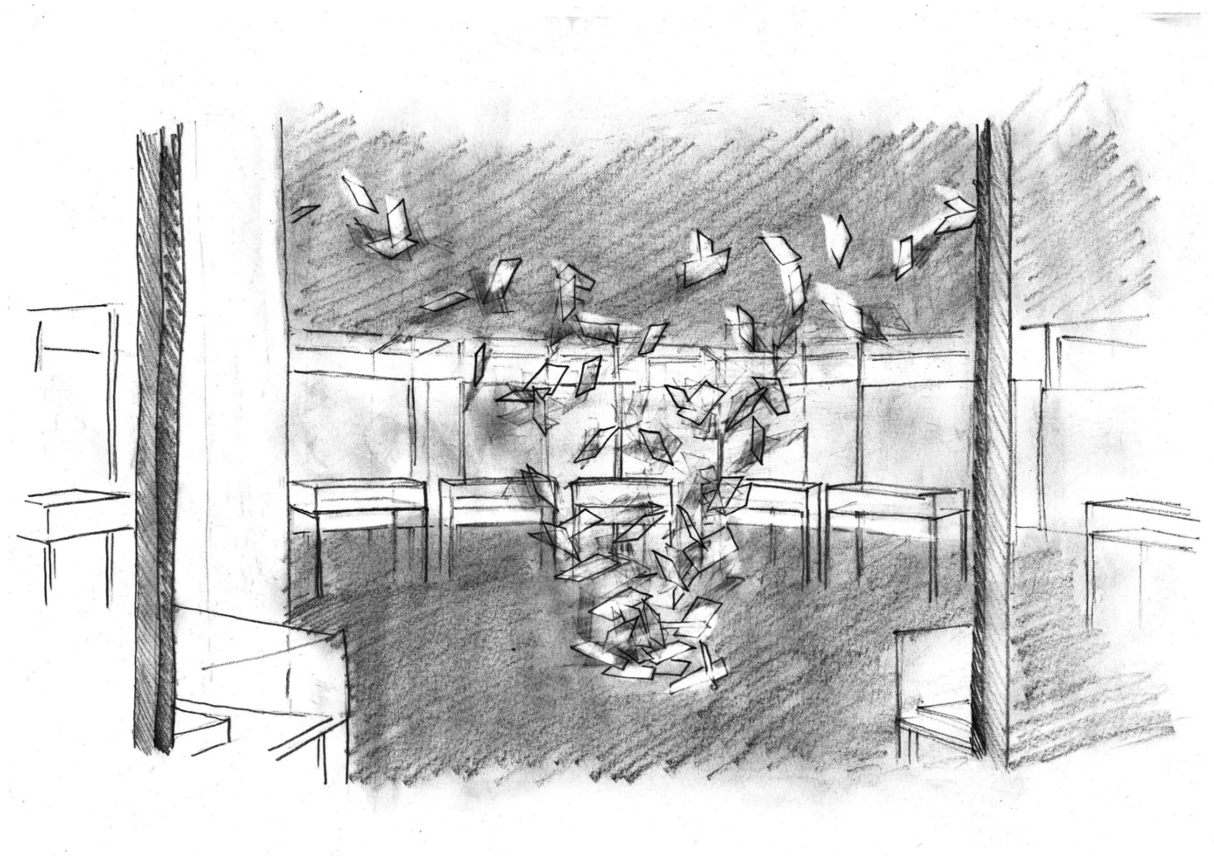

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In Memory of Peter Damerow
1939–2011

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Greetings

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Jürgen Renn
Director at the Max Planck Institute for the History of Science

Every part of a thing contains something of the nature of the whole
Leonardo da Vinci
Paris MS I, fol. 90r

No battle noise could be heard, only the rippling waters of the nearby river. Even time flowed more languidly now, or so it seemed in this peaceful landscape. But everything was in flux in the late summer of 1502, and not only in central Italy. It was a time of rapid change, bold plans, swift conquests, and breaking orders.

Was there nevertheless a deeper order hidden behind all the turbulence, of the water and perhaps also of the vicissitudes of human history?

One had only to observe very carefully, and of course record what one saw—no, to be able to recreate from an understanding of the inner efficacy of things, to be inventive in doing so, perhaps even more inventive than nature itself, always seizing the opportunities of the moment—but all that was apparently not enough.

It was necessary not only to grasp the world in its entirety, to make it one's own, but also to acquire its knowledge, all the knowledge, including the lost knowledge of the Ancients, the long-neglected knowledge that was now circulating again in broader streams.

This was thanks to the obsessive hunters and collectors of ancient texts; texts that had long been gathering dust and decaying in old libraries or attics but had now been given a new lease on life, so that their authors were now contemporaries with whom one could converse, one could imitate, and, if possible, even surpass.

But to enter into conversation with them, one had first to find them. After all, mechanics helped the new technology of printing, yet another prodigy of that art that so generously endowed the age with inventions, both martial and peaceful, and whose cornucopia was far from exhausted.

Being in exchange with the world did not only mean socializing with other artists, architects, engineers, and mechanics, nor simply feeling at home in workshops and on construction sites. It did not just mean impressing soldiers, army commanders, diplomats, literati, and politicians at courts and palaces with clever and elegant speeches and promising plans and projects. Nor was it enough to occasionally leave the cities to wander through mountains and valleys and rural towns like these, where one could quietly watch birds fly, to consider whether this was not perhaps another mechanical art that could be surpassed.

The notebook, whose cover might once have been as light blue as the sky over the valley, was the only companion on the walk that afternoon, a silent yet eloquent counterpart, a mirror of time that allowed one to converse with the past and future self, and to which one could confide one's thoughts, even if no one else might yet understand them: "The bird is a machine that works according to mathematical laws."

With whom might one speak about it? From whom could one learn more about the secrets of mechanics, wrapped as they are in the language of mathematics, the most difficult but perhaps most fruitful of all languages? The ancients had probably mastered it best, and from them one could learn more about the lost and to be regained paradise of mechanics, where one could reap the fruits of mathematics.

Rapid change, conquests, and shifting rulers, the hustle and bustle of such notorious *condottieri* as Cesare Borgia and Vitellozzo Vitelli also had advantages for someone who was not on a reckless hunt for power but rather for knowledge. And who did not hesitate to seize the moment, especially when it came to winning over such an important interlocutor as Archimedes, the prince of mechanics, for his endeavors. A short note in the booklet with the light blue cover is intended to remind the future self not to let opportunities pass by:

> Borges will get you the Archimedes of the Bishop of Padua, Vitellozzo, the one that is in Borgo San Sepolcro.

Hunting down and collecting books, even stolen ones, and building up a library was a bold undertaking in those days, an *impresa* comparable to the campaigns of the *condottieri*, undertaken at one's own risk but promising the reward of conquering an intellectual realm and creating one's own intellectual cosmos.

The historical reconstruction of Leonardo da Vinci's unique book collection is just such an *impresa*, and its realization in an exhibition with a selection of valuable historical books even more so. *Imprese* are undertaken in adventurous company. It includes masterminds, courageous pioneers, generators of ideas, architects, engineers and craftsmen, scholars, students, artists, lenders and donors, and other supporters of diverse expertise and provenance. They have all worked together to make the exhibition "Leonardo's Intellectual Cosmos" a new look at one of the most fascinating figures in cultural history. So, enter Leonardo's Berlin library and welcome to his intellectual cosmos!

According to history of science, the practice of craftsmanship and of art, and artists who were also scientists, and scientists who were also engineers—from Leonardo to Galileo—played a decisive role in the emergence of modern science. In the case of Leonardo, the main focus of interest has been on his inventions and technological visions. This has led to a distorted image that ultimately denies him any deeper intellectual context. But a systematic and careful study of Leonardo's manuscripts shows us an artist, scholar, and scientist who had an intimate relationship with books, culture, and the authors of his time, as well as those of classical antiquity.

Based on the important work of the Italian scholar Carlo Vecce (*La biblioteca perduta. I libri di Leonardo*, Rome 2017), the Max Planck Institute for the History of Science (MPIWG), together with the Museo Galileo in Florence, had planned to exhibit "Leonardo's Intellectual Cosmos" in Berlin on the occasion of the 500th anniversary of Leonardo da Vinci's death and the 25th anniversary of the founding of the MPIWG. Research on the Renaissance plays a central role at our institute, which has maintained diverse partnerships and collaborations with institutions in Italy since its founding in 1994: in Florence with the Museo Galileo, the Opera del Duomo, and the Kunsthistorisches Institut, as well as with the Bibliotheca Hertziana in Rome (both institutes of the Max Planck Society), the University of Urbino, and the Centro Internazionale di Studi Telesiani, Bruniani e Campanelliani in Cosenza.

The exhibition is an adaptation of the Florentine exhibition "Leonardo and his books: the library of the universal genius," curated by Carlo Vecce and shown at the Museo Galileo from June to September 2019. Due to the global coronavirus crisis, the date for the Berlin exhibition had to be postponed twice so far. I would like to take this opportunity to thank all the organizers, institutions, speakers, artists, and exhibition guests for their patience and flexibility throughout the planning process. As this volume goes to press, the scheduled date for the opening, May 10, 2021, falls in the year in which we celebrate the 700th anniversary of the death of Dante Alighieri, whose *Divine Comedy* formed a significant reference point in Leonardo's intellectual cosmos. Pandemic situation permitting, the exhibition will be open to visitors from May 11 to June 28. The MPIWG will accompany the exhibition with scholarly and public activities and events. Rather than focusing on Leonardo as a precursor to the modern technological world, the exhibition honors his art and science, his thought and practice, as part of a distinct intellectual world. For Leonardo, this included the endeavor to never separate theory from practice and to perceive this world as a whole, to constantly question its apparent fixed points and thus keep it in constant motion.

A further goal of the exhibition project is to illustrate the value of the far-reaching intellectual networks and mutual connections that have fostered the development of science and culture since the early modern period. The reconstruction of Leonardo's library and its presentation in the exhibition opens a new perspective on Leonardo, showing him as an intellectual and artist-scientist whose work was only made possible by the diversity of such connections and networks.

The exhibition places Leonardo's library in the context of the burgeoning book culture at the turn from the 15th to the 16th centuries and illustrates the role this culture played in his intellectual development and creative process. While the scholarly work of identifying the books by deciphering Leonardo's notes and lists can be considered almost complete, the way in which these books were collected and actually used in his library is still the subject of debate and research.

Looking back at the book culture of the Gutenberg era is more relevant today than ever before, confronted as we are with the challenges of a new media revolution that makes it possible, in principle, to make the accumulated knowledge of humankind available to every single person. We are still far from shaping an intellectual cosmos that exploits this potential of the new media, and instead run the risk of losing it in an unmanageable fragmentation and amalgamation of information and disinformation.

Over the past two years, the exhibition project has evolved into a multifaceted endeavor that, in turn, could not have been realized without wide-ranging networks and the cooperation, support, and hard work of many institutions and individuals who I will mention below.

First of all, I would like to thank our long-time cooperation partner, the Museo Galileo, especially its director, my friend of many years, Paolo Galluzzi, and his entire team, particularly Laura Manetti and Jacopo Tonini, who inspired us to undertake this project. Their collaboration and support from the beginning has laid the foundation for all further developments. In addition, Alessandro Nova from the Kunsthistorisches Institut in Florence and Carlo Vecce from the University of Naples have accompanied and supported the project with their incredibly broad knowledge of Leonardo—from the development of the first idea to its realization in the exhibition. We thank Paolo Galluzzi, Carlo Vecce, and Alessandro Nova from the bottom of our hearts for their continued support and commitment. Through their lectures at our 2019 Leonardo Symposium ("Leonardo da Vinci. An Inquisitive Man: Technologist, Scientist and Artist") on the occasion of the 500th anniversary of Leonardo's death and their contributions to this catalogue, they have made their knowledge available to a wider audience.

Without the generous funding from our partners, the NOMIS Foundation, this project would certainly not have come about. We owe the contact to Dr. Barbara Bludau, the former secretary general of the Max Planck Society. We would like to sincerely thank the representatives of the NOMIS Foundation, Markus Reinhard and Ruben Garcia Santos, for their support and especially for believing in the potential of the exhibition when it was only a rough sketch on a sheet of paper. Their flexibility and encouragement at all stages of the project’s development have brought us to where we are now.

It is obvious that an exhibition of books is inconceivable without the close cooperation and support of the institutions that preserve them. Our thanks here go to Hermann Parzinger, president of the Stiftung Preußischer Kulturbesitz (Prussian Cultural Heritage Foundation), who has generously encouraged the project from the outset. We would like to give a special thanks to the Staatsbibliothek zu Berlin (Berlin State Library) and its director, Barbara Schneider-Kempf, as well as to Gudrun Nelson-Busch, Falk Eisermann, and the entire team. As curators, they have not only identified and made the crucial books available but have also generously supported the realization of the exhibition and its opening events. Over the past months, they have been our close collaborative partners in all matters of coordination, book restoration, and, of course, the presentation of the books in the exhibition. In this context, we would also like to thank our colleagues at the Kupferstichkabinett (Museum of Prints and Drawings) and the Kunstbibliothek Berlin der Staatlichen Museen zu Berlin (Berlin Art Library of the National Museums), who also provided books that proved to be valuable additions to the exhibition.

Given the overarching theme of commemorating Leonardo da Vinci on the 500th anniversary of his death, we have worked closely with the Italian Embassy in Berlin. At this point, I would like to sincerely thank His Excellency Ambassador—and patron of the exhibition—Luigi Mattiolo, as well as First Counsellor and Head of the Cultural and Economic Section of the Embassy, Francesco Leone, former Scientific Attaché Matteo Pardo and the entire team at the Embassy for their partnership. They were not only our partners in organizing the Leonardo Symposium in April 2019, held at the MPIWG and the Italian Embassy, but they generously supported us in all phases of the project and in all accompanying events.

Special thanks also go to the Governing Mayor of Berlin, Michael Müller, for his contribution to our Leonardo Symposium and his continuous support in making the exhibition a reality, despite his burden as a responsible politician in the difficult times of the Corona pandemic.

The mastermind behind the exhibition design is our architect Serge von Arx, who already shaped our large Einstein exhibition in 2005. I would like to express my deepest gratitude to him and his team, especially also to Andreas Fuchs and Armin Schreiter. We owe the exhibition in its current form to their creative and tireless work.

In order to place Leonardo’s books in the context of his life through exemplary objects, we have embarked on a seemingly endless search for suitable exhibits. At this point, I would like to especially thank the director of the Museum für Naturkunde (Natural History Musuem) Johannes Vogel and his team, as well as Joachim Breuninger and Kerstin Wallbach from the Stiftung Deutsches Technikmuseum (German Museum of Technology), Felix Lühning, Director of the Archenhold Observatory, and again the colleagues from the Staatsbibliothek zu Berlin and the Museo Galileo for their support, which went far beyond providing key exhibits.

Last but not least, I would like to thank the entire team at the MPIWG for their hard work on this project, first and foremost Matteo Valleriani, who not only played a major role in shaping the exhibition concept but was also the driving force in bringing its ideas to life. The curatorial team also included Antonio Becchi, whose knowledge of Leonardo and his work was of crucial importance to our joint work, and Sabine Hoffmann, whom I would like to thank especially for producing the excellent texts that form the link between the exhibits,

the books, and Leonardo’s scientific themes, and who thus played a major role in bringing Leonardo’s intellectual cosmos to life.

Editing the catalogue in German and English was in the proven hands of the Publication Manager of Department I of the MPIWG, Lindy Divarci, who mastered this Herculean task in record time with assistance from Elizabeth Hughes. Mona Friedrich and Lina Schwab mastered the planning and coordination of the processes and the communication internally and externally with aplomb. Nina Bätzing and Vivienne Rischke contributed imaginatively to all components of the exhibition, from the object search to the bibliography to the design of exhibits. Dirk Wintergrün and his team, in close collaboration with the Museo Galileo team, have created a virtual exhibition making Leonardo’s Berlin library available online. On the part of the MPIWG, Ohad Parnes, Hans-Jakob Ziemer, and Jörg Fischer have worked diligently on sponsorship, press relations, and the organization of the 2019 Leonardo Symposium, not to mention contracting. Thanks also go to the MPIWG administration, whose work behind the scenes cannot be underestimated. Finally, a very special thank you goes to Sabine Bertram and the entire library team led by Esther Chen. Without their extremely thoughtful and dedicated help, there would be no Berlin Leonardo Library.

Last but not least, we would like to thank Claudio Pescio and his entire team at Giunti Publishing, especially Dario Dondi, Lorenzo Mennonna, and Elisabetta Marchetti. They have given this volume the appealing design in which it is presented here.

Paolo Galluzzi
President of the Italian National Committee for the Commemoration of the 500th Anniversary of the Death of Leonardo da Vinci – Director of the Museo Galileo, Florence

While referring to himself as an “unlettered man,” Leonardo did not limit himself to learning and accumulating knowledge only through the direct study of natural phenomena. He devoted equal attention to an intense dialogue with both ancient and modern authors. With the passing of the years he became not only a passionate reader, but also an insatiable hunter of books and manuscripts. He regarded these texts as precious maps which indicated unexplored paths to knowledge that he could follow to reach original insights and awareness. By the time of his death, he owned almost 200 works: an extraordinary library for a 15th-century artist-engineer, not only in terms of quantity, but also for the variety of disciplines covered. Leonardo carefully recorded these volumes in his manuscripts to ensure that he could safely retrieve them when he returned from one of the many journeys undertaken during the course of his lifetime.

Unfortunately, the books and manuscripts accumulated by Leonardo have disappeared without trace. Only one exemplar of the texts that went their various ways after his death has survived: the *Treatise on Architecture and Machines* by Francesco di Giorgio, the splendid parchment manuscript preserved in the Biblioteca Medicea Laurenziana in Florence, on which Leonardo registered 12 annotations.

Through his long-term commitment to exploring the manuscripts and documents on the life and works of Leonardo, the renowned Leonardo scholar, Carlo Vecce, has reconstructed the contents of Leonardo’s library. He has also provided valuable information on the stages of Leonardo’s acquisition of these complex resources with which he maintained a constant and fruitful dialogue. The results of this thorough investigation are available to the international community of Leonardo scholars thanks to the book titled *La Biblioteca di Leonardo*, recently edited by Carlo Vecce (Florence 2021).

The impressive work accomplished by Vecce, in collaboration with dozens of specialists from the multiple disciplines on which Leonardo the bibliophile focused his inexhaustible curiosity, constitutes a landmark in Leonardo studies. For the first time, students of the Universal Man have at their disposal an exhaustive list from which to draw reliable information on the sources that inspired him. Leonardo was never a passive reader; he combined admiration for the authors of the texts that intrigued him most with his instinctive inclination to question their conclusions or to test them for their reliability.

La Biblioteca di Leonardo is a work to be used in conjunction with the Digital Library of his Books and Manuscripts, published by the Museo Galileo (https://bibliotecadileonardo.museogalileo.it). This freely accessible tool is indispensable to understanding the impact on Leonardo’s literary, artistic, technical, and scientific production of the resources that he consulted. The creation of this formidable resource was made possible by the generosity and collaboration of the libraries and cultural institutions that authorized the digitization of the valuable historical documents they preserve.

The exhibition *Leonardo and his Books: The Library of the Universal Genius* was a milestone in the research project that culminated in the publication of the above-mentioned volume. It was first staged in the summer of 2019 by the Museo Galileo in collaboration with the Commission for the National Edition of the Manuscripts and Drawings of Leonardo da Vinci, and with the patronage of the National Committee for the Commemoration of the 500th Anniversary of the death of Leonardo da Vinci. From Florence, the exhibition moved to

Rome, where it was displayed at the Accademia dei Lincei. The exhibition effectively contributed to disseminating awareness of the strategic role played by books and manuscripts in Leonardo's intellectual development and in nourishing his programmatic interdisciplinary approach.

It is immensely satisfying to see that this exhibition will now return to the stage in a new and enriched format, in line with the spirit of continuous improvement that characterized Leonardo's mind and his thirst for knowledge. This enhanced version of the original exhibition is the outcome of the commitment and scientific competence of the authoritative colleagues of the Max Planck Institute for the History of Science in Berlin. Through the Director, my friend and colleague Jürgen Renn, I would like to express my deepest admiration and most sincere congratulations to all the scholars of this prestigious research institution who have brought this ambitious project to fruition despite the difficulties posed by the Covid-19 pandemic, which continues to scourge the planet as I write.

I would like to express my gratitude and appreciation also to Barbara Schneider-Kempf, Director of the prestigious Staatsbibliothek zu Berlin, who believed in this project from the start, and to the Italian Ambassador in Berlin, S.E. Luigi Mattiolo, who offered, together with the Istituto Italiano di Cultura, his valuable encouragement and support for the presentation of this exhibition in the capital of the Federal Republic of Germany.

Ulman Lindenberger
Vice President of the Human Sciences Section of the Max Planck Society

It gives me great pleasure to welcome you as visitors to the exhibition and readers of the catalogue *Leonardo’s Intellectual Cosmos*. The exhibition team, led by Jürgen Renn, has succeeded admirably in bringing the project to a conclusion in times of pandemic. The team as well as the participating institutions—the Max Planck Institute for the History of Science, the Staatsbibliothek zu Berlin, the Museo Galileo, the Ambasciata d’Italia a Berlino, and the NOMIS Foundation—all deserve our great thanks.

Whereas Leonardo is known to the public primarily for his artistic masterpieces, this exhibition takes a look at his contemporaneity. Which works did Leonardo read? What knowledge did he possess when he embarked on his own studies? To get answers to these questions, the exhibition organizers have reconstructed Leonardo's library. Since Leonardo's own books are lost, they have assembled the Berlin Leonardo Library from comparable contemporary works. The volumes come from Berlin holdings, especially from the Staatsbibliothek, but also from the library of the Max Planck Institute for the History of Science. They now bear witness to the knowledge that made up Leonardo's intellectual cosmos.

The contrast between Leonardo’s books and his own notes is particularly revealing. Leonardo’s notebooks show the unfinished, experimental, super-richness of his work. A beautiful example is offered by the first exhibit of the exhibition (1 □). On this sheet, Leonardo presents geometry exercises for the transformation of different rectangles. Suddenly the argumentation breaks off with a terse “*ecc.*” referring to the possible, perhaps even intended, continuation of the discourse. He also communicates the reason that forces the sudden interruption: “*ecc. perché la minestra si fredda*.” Because the soup is getting cold, the studies will have to be resumed at a later point in time—if they do not turn to other subjects altogether.

Leonardo was less interested in specific objects than in their transformation, dynamics, and functionality. In his work, aesthetics and mechanics are not opposites; they are mutually dependent. What astonished me most was the enormous precision with which he took notice of complex dynamic systems. Drawings of the turbulence of water, illustrated notes on the flight of birds, and the unrealized bronze sculpture of a rearing horse with rider are outstanding examples of Leonardo’s stupendous ability to observe and depict complex movements.

Thanks to the exhibition, we can now trace the intellectual cosmos that enabled and accompanied Leonardo’s life journey. But human development is itself a complex dynamic system. Therefore, neither the reconstruction of Leonardo's intellectual cosmos nor psychoanalytical interpretations of his early childhood can explain his uniqueness. Great talent and favorable circumstances enabled a self-reinforcing process that follows its own laws. We, as an awed audience, are now given the opportunity to follow it.

Hermann Parzinger
President of the Prussian Cultural Heritage Foundation

The exhibition on the artist and scientific genius Leonardo da Vinci, held in 2021 at the Berlin State Library – Prussian Cultural Heritage Foundation and organized in cooperation with the Max Planck Institute for the History of Science in Berlin with the sponsorship of the Italian ambassador, comes two years late; it was supposed to commemorate the 500th anniversary of Leonardo's death in 2019. But it is never too late to engage with the intellectual cosmos of this *uomo universale* of the early modern period. A reconstruction of Leonardo's library, which provided the foundation and source of his knowledge, creation, and discovery, makes up the core of this exhibition. In this respect, there really is no better place for this presentation than the largest general scholarly library in the German-speaking countries: the Berlin State Library.

The museums, libraries, and research institutes of the Prussian Cultural Heritage Foundation possess world-class collections and holdings of encyclopedic character. The fundamental break between the Middle Ages and the modern era known as the Renaissance, which particularly influenced Leonardo, is represented by significant works in the collections of the Berlin State Museums as well as the Berlin State Library. Only Leonardo da Vinci is missing: the Foundation owns neither manuscripts nor incunabula nor noteworthy early printings, nor any works of art that can be conclusively attributed to him. Then again, original copies from his reference library have not been preserved anywhere else either; and so the only course of action is to collect the texts that he must have owned and that may have influenced him, even if the copies and editions shown here have no direct connection to the master.

Wilhelm von Bode believed he could fill this gap in 1909, at least for the collections of the Berlin State Museums, when he acquired a wax bust of the Roman goddess of flowers, Flora, for the Kaiser Friedrich Museum (now the Bode Museum) and attributed it to Leonardo da Vinci. After it was made public, however, this purchase provoked an unprecedented scandal in the press regarding the sculpture's attribution, a discussion that still holds art historians in its thrall today, though far more than 700 articles, studies, and investigations have already tackled the topic. Leonardo is thus an object of interest for the Berlin collections of the Prussian Cultural Heritage Foundation mainly because of the question of whether he is represented in them or not; much evidence speaks for the latter.

Leonardo da Vinci remains an exceptional figure in the history of European art and science. But his brilliant universality is reminiscent of a famous Berliner whose 250th birthday fell in the same year as the 500th anniversary of Leonardo's death: Alexander von Humboldt. Both are rightly regarded as polymaths and untiring geniuses, though the one was more of an artist and the other more of an explorer. Each lived in the most important political, economic, and intellectual metropolis of his time, in the wake of profound upheavals: Leonardo in Florence after Savonarola's reign of terror, Alexander in Paris after the French Revolution. Both encountered the most important rulers of their time: Leonardo met Cesare Borgia, the pope and the French king; Alexander met the Prussian kings Frederick Wilhelm III and IV, Thomas Jefferson, and Napoleon. Both were path-breaking inventors: Leonardo developed diving suits and a variety of futuristic machines, while Alexander created mine lamps and breathing devices. Both believed in the beauty of nature and the unity of humans and nature, and both described and drew plants and animals. Both were active as geologists and geographers: Leonardo took interest in clouds and the tides in the Black Sea and Caspian Sea, while Alexander looked to the Humboldt Current and other natural phenomena in Latin

America. And both wrote their observations and discoveries down in diaries that they added to constantly: Leonardo in his famed *codici*, notebooks that he wore on his belt; Alexander in the diaries that he constantly had at hand on his voyages of discovery. And this reveals what may be their most important difference: while Leonardo's *codici* are largely scattered today, Alexander von Humboldt's travel diaries and other holdings are preserved in the Berlin State Library in exemplary fashion, indexed and made available for research.

Memory institutions and archives of knowledge such as the State Library and other organs of the Prussian Cultural Heritage Foundation once again have demonstrated their potential when it comes to making the achievements of unique and significant artists and scholars of previous eras comprehensible, placing them in the context of their times and thereby allowing them to speak to us, bringing them to life for us. This exhibition is an impressive confirmation of the feats of transmission that memory institutions are capable of performing. Doing so, however, also requires bringing together differing and complementary abilities. Thus, it proved fortunate that the Max Planck Institute for the History of Science came together with the Berlin State Library—Prussian Cultural Heritage Foundation for this fruitful collaboration. The initiators of the exhibition and all of those who made it possible deserve our thanks for making Leonardo da Vinci and his impact on his era accessible to us in a completely new and very special way.

Barbara Schneider-Kempf
General Director of the Staatsbibliothek zu Berlin

How particularly suitable for an exhibition on Leonardo's intellectual cosmos is the Staatsbibliothek zu Berlin (State Library) with its site on the Kulturforum. By definition, a library is above all the physical manifestation of a spiritual world, basically its embodiment. What's more, were he alive today, Leonardo would certainly feel very much at ease in the Staatsbibliothek. Here he would find literature for his studies of architecture, geometry, statics and dynamics, anatomy, and mathematics. He would only have to take a brief walk across the street to have a look at paintings by the great talents of his time, and discover further locations for his work at the Kupferstichkabinett (Museum of Prints and Drawings) and the Kunstbibliothek (Library of Art History), which also happen to have contributed to his exhibition. Widening the circle, Berlin is a city where science and technology, along with art give ample grounds for cooperation between research institutes, libraries, and museums, providing a solid basis from which to consider the thought of one of the most famous polymaths in cultural and intellectual history.

Despite all the modernity that we like to ascribe to the very early originators of technical concepts first realized centuries later and all connections to the present that can be demonstrated, we must keep in mind that researching during the Renaissance posed challenges unknown to us today. A private library such as the one that Leonardo called his own was in no way to be taken for granted. That makes it all the more exciting to reconstruct the library by using surviving book lists. Even if very little of Leonardo's collection was preserved, this presentation, which relies to the greatest degree possible on editions available then, gives insight into the foundations available to Leonardo.

Taking the image of today's science as the "dwarfs sitting on the shoulders of giants," Leonardo is undisputedly one of those giants who have shaped and influenced science for more than 500 years since his death. The recreation of his library in the exhibition and in this catalogue makes clear, however, that this giant was already sitting on the shoulders of others.

I am very pleased that the Staatsbibliothek could provide the exhibition venue, as well as numerous important manuscripts and prints from our collection, and last but not least the expertise of our specialists, in order to play a significant role in this cooperation with the Max Planck Institute for the History of Science and the Museo Galilei di Firenze.

Markus Reinhard
Managing Director, NOMIS Foundation

NOMIS, a private Swiss foundation, strives to “create a spark” in the world of science by enabling, funding and supporting pioneering research in the natural and social sciences as well as the humanities. Hereby, NOMIS aims to serve as a catalyst for scientific and human progress by fostering interdisciplinary research, establishing collaborative research networks and developing strategic partnerships.

A master of interdisciplinary study himself, Leonardo da Vinci was a pioneer in the co-evolution of science, technology, and the arts. His intense curiosity led him down a vast array of intertwining intellectual paths as he strove to make connections in all aspects of nature and our human existence. Navigating seemingly disparate disciplines was a lifelong personal quest that would lead to significant new insights about our world.

Leonardo and his work exemplify the kind of curiosity-driven, pioneering researchers and novel inquiries that inspire and drive the NOMIS Foundation. Supporting the development of the virtual library of Leonardo’s private collection of books—a collection that served as the source of much of Leonardo’s vast knowledge—was thus an irrefutable means for NOMIS to advance our mission of enabling curiosity-driven interdisciplinary research endeavors.

We are very excited about the Leonardo’s Intellectual Cosmos project and to be witness to the incredible collaborative effort with the Max Planck Institute for the History of Science—an institution that shares NOMIS’ high regard for fundamental, interdisciplinary research—as well as the Berlin State Library and the Museo Galileo, to name just a few of the organizations behind this remarkable undertaking. Together, as we explore Leonardo’s role in the history of knowledge, we are discovering the innumerable connections in the world and realizing the significance of continued interdisciplinary research in our pursuit of answers to the important questions and challenges facing humanity today.

Luigi Mattiolo
Ambassador of the Italian Republic to Germany

When we think of Leonardo da Vinci, the term “universal genius” springs to mind, by which we mean a highly talented person whose intellect can move flexibly between various disciplines, creatively combining various forms of knowledge. In this context, the word “universal” also acquires a second, geographical meaning that is derived from the first: a universal genius quickly becomes an international intellectual figure who is recognized worldwide precisely because their actions are innovative and influential.

As the Italian ambassador, this second significance of Leonardo da Vinci as a universal genius is just as important to me as the first, because it highlights his international impact as a historical figure. This is made particularly clear in the exhibition “Leonardo’s Intellectual Cosmos”: even in his time, the intellectual constellation in which Leonardo moved was *international*, from the knowledge of Greek antiquity to his contemporaries throughout all of Europe.

Leonardo’s works and discoveries were *internationally* recognized and are admired today throughout the world, in Milan and Florence just as in Paris, London, and St. Petersburg. This exhibition is also *international* itself, because it is the result of international *cooperation*, particularly between Italian and German cultural institutions. It is based on the research of Prof. Carlo Vecce of the Università L’Orientale in Naples and was first opened at the Museo Galileo in Florence in cooperation with the Max Planck Institute for the History of Science (MPIWG) Berlin. Thanks to the engagement of the Museo Galileo and the MPIWG, the exhibition went on tour and can now also be seen at the Berlin State Library. We are deeply thankful for the engagement of all of those involved during this difficult pandemic, at a time when all forms of international cooperation in the cultural sector are confronted with once unthinkable obstacles and limitations—particularly when it comes to organizing a physical exhibition. Under these conditions, this initiative is a brave gesture and a hopeful signal for the world of culture.

For this reason, I am particularly proud that the Italian Embassy in Berlin supported this undertaking from its inception, on April 10, 2019, when the Berlin exhibition was announced for 2020 at the MPIWG conference as “Leonardo da Vinci. An Inquisitive Man: Technologist, Scientist and Artist.” Due to the pandemic, it had to be delayed until 2021, which is why it now falls in the same year as another important date, the 700th anniversary of the death of Dante Alighieri, one of Leonardo’s great masters who was certainly represented in the library of this “not well-read man” (as Leonardo mocked himself because he could not read Latin). What historical figure embodies Dante’s famed verses from canto 26 of *Inferno* better than the autodidact Leonardo: “Considerate la vostra semenza: Fatti non foste a viver come bruti, / ma per seguir virtute e canoscenza”? (“Consider how your souls were sown: you were not made to live like brutes or beasts / but to pursue virtue and knowledge”—translation by Robert Hollander and Jean Hollander). Let us take this symbolic passing of the torch as a good omen.

“Leonardo’s Intellectual Cosmos” consists not only of physical items on display—his books and manuscripts, as well as the reconstruction of his atelier—it is also rounded out with digital elements when the originals were missing. Thanks to the newest *digitization technology*, the most precious and oldest manuscripts from Leonardo’s library have been digitized, linked to his works, and can be made available open access to a worldwide public.

Under the current conditions, there is an urgent demand for new solutions in our knowledge economy. This exhibition helps us to approach this question because it shows us how the field of the *digital humanities* can contribute to enhancing and spreading our knowledge, and it demonstrates that the expertise of historians and philologists is indispensable. It brings together international experts on the Florentine Renaissance and the most renowned European institutions in the field of the digital humanities. This complementary use of traditional philological methods on the one hand and the newest digital means on the other helps us not only to better comprehend the past in which Leonardo lived and worked, but also to recognize how our knowledge will be shaped and shared in the future.

For months, we have been living in uncertain times whose consequences are to be felt in all areas of life. *Archives and libraries* are just as deeply affected by the pandemic as start-ups and businesses. For public health reasons, many of them are currently only accessible in a limited way, if at all. This delays or even prevents the work of many historians, philologists, political scientists, and sociologists, whose research contributes to public discourse. If we go for long without their valuable contributions, it may have grave long-term effects for public democratic debate in our countries.

But what if this crisis situation spurs us to solve problems that also existed before the pandemic? Let it be mentioned that Leonardo himself survived the 1484 outbreak of the plague in Milan. This experience prompted him to think about how quality of life in the city could be improved. And so he developed the first concept for a garbage removal service in Milan. In more recent times, the project of European integration arose from awareness of the horrors of the 20th century. Times of crisis have always been the driving force behind innovation. The highest *cultural institutions in our nations* have quickly recognized the need for innovation and made the corresponding financial means available for digitization in the cultural sector.

What would the universal genius Leonardo da Vinci have done in a similar situation? We will never know the answer to that question, and it wouldn't make sense to speculate about it, especially in this highly advanced scientific context. However, we can learn from the example of how Leonardo approached the new media of his day: at that time, the printing press was still a relatively new technology that came to Italy from Germany at the end of the 15th century, when Leonardo was a rising young artist completing his apprenticeship. Thanks to the printing press, books became more affordable and accessible. Without this invention, Leonardo could hardly have had access to the knowledge of antiquity and of his era, to say nothing of the possibility of building a private library with the then-impressive number of approximately 200 books. And so he is what we might now call a "print native." He never hesitated to take advantage of the opportunities provided by the newest technological achievements—and with this intellectual attitude he remains a model for us today.

The Exhibition

Images of the exhibition
High_Res_Canovaccio

The Structure of this Catalogue

All exhibits have a consecutive catalogue number that enables cross-referencing within both the catalogue and the exhibition.
A three-color scheme, also featured in the logo of the exhibition, as well as the symbols triangle △, square ☐, and circle O further facilitate orientation:

The color red and the triangle △ stand for Leonardo himself, identifying all the objects, writings, and works of art in whose creation he was directly involved.

Light blue and the square ☐ stand for the intellectual, for Leonardo's access to the knowledge of his time and thus his library, which is divided into ten thematic sections—as is customary for libraries—according to the content sections of the exhibition.

Green and the circle O stand for the cosmos, for the totality of the interrelationships and contemporary contexts of Leonardo's work and thinking.

The epilogue presents a selection of Leonardo's manuscripts, the codices, and relates them to the individual sections of his library.
A separate chapter examines Leonardo's life and legacy.

Catalogue entries: Sabine Hoffmann

Guide

Images:
[Grundriss_TIFF]
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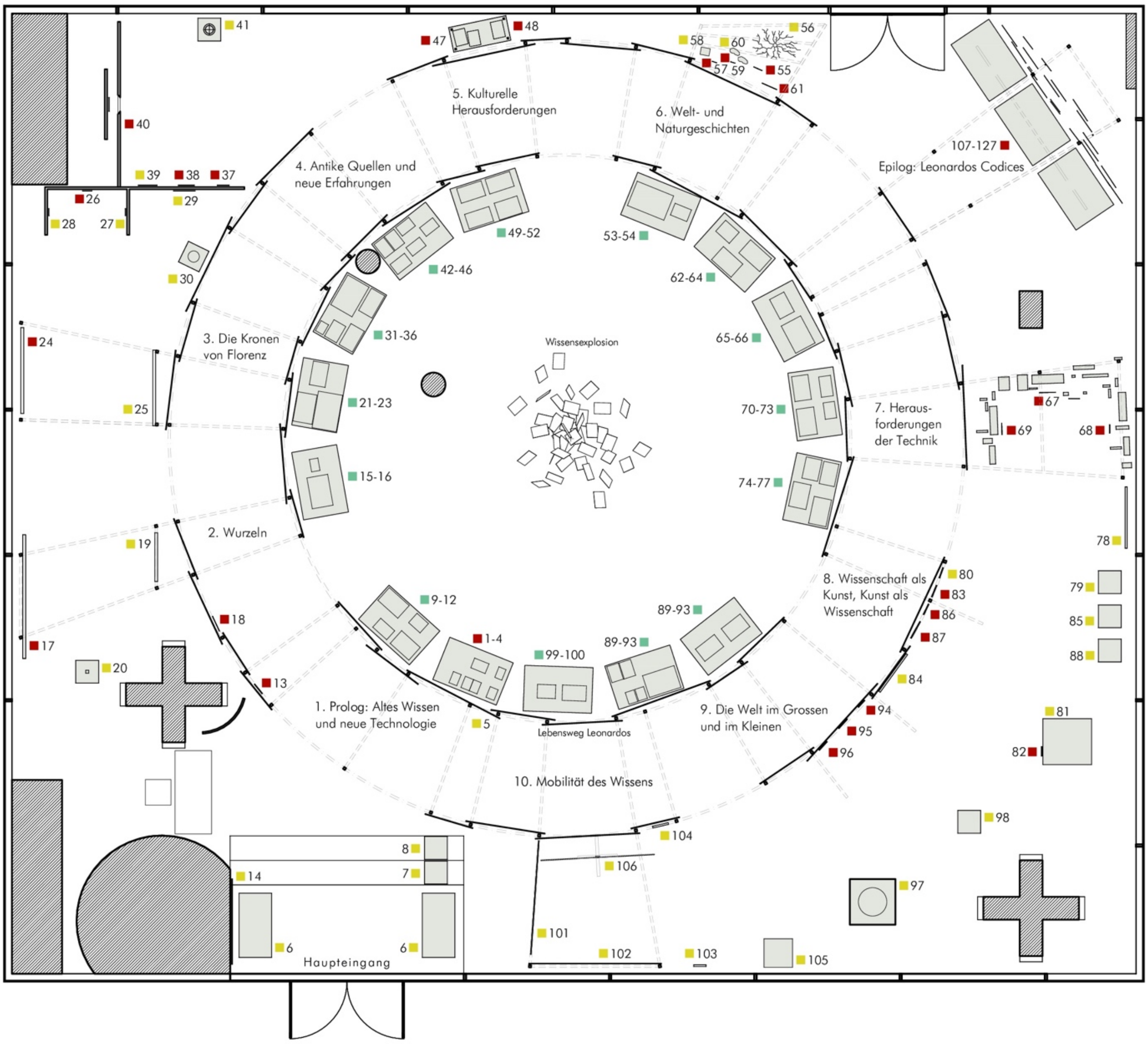

Leonardo’s Intellectual Cosmos

The intellectual cosmos of Leonardo da Vinci (1452–1519) is seemingly inexhaustible. It echoes the diversity and cultural abundance of the Renaissance, which he embodies in all its facets like few others of his time. He applied his curiosity and creative commitment to all fields of knowledge, from the forces of nature, both large and small, to all varieties of human form and design.

Leonardo’s era was characterized by upheavals: the rediscovery of antiquity, the rise of trade and science, the invention of printing, the European discovery of America, and the beginnings of a new astronomical worldview. The tensions affecting his time included those between Christianity and the revived pagan antiquity, faith and science, bourgeoisie and feudal society, new technologies and the traditional social order. The great emphasis placed on the highest level of individuality of human actors stood in contradiction to the aspiration of their thinking to universal validity, while the growing potency of art began to compete with the forces of nature. All this took place alongside disruptive experiences of war, crises, and diseases such as the plague—but also the challenge posed by the new possibilities of thought, belief, and action.

Leonardo and other contemporary artists, scientist-engineers, and humanists struggled to balance out these tensions in their work, although not at the price of flattening them or accepting one-sided solutions. Instead, they succeeded in giving expression to these tensions in their creative works and using them productively. The willingness not to conceal contradictions, but to battle through them in a constant dialogue with oneself and others, was considered a virtue. Leonardo’s intellectual cosmos was deeply influenced by contradictions, such as his quest for the structural and dynamical harmony of the world and his willingness to find this harmony in a never-ending diversity of details, to each of which he devoted all his attention and skill.

The much-discussed antithesis between observation of nature and traditional scholarship through books was another issue Leonardo refused to deal with one-sidedly, tackling both aspects with great commitment. Compared with his predecessors, he was almost unique in how he perceived the diversity of nature, at the same time using the new medium of book printing to build up a remarkable library that influenced and corresponded to his own worldview.

To a large extent, Leonardo’s library could be reconstructed from his manuscript notes. It was unique yet reproducible. This is made clear in this exhibition, which gathers a number of works from his library, but not his personal copies, which—with possibly one exception—have not survived. Instead, the “Berlin Leonardo Library” has been compiled from contemporary works from the holdings of libraries in Berlin. In particular, they include the Staatsbibliothek zu Berlin (State Library of Berlin), the Kunstbibliothek (Art Library), and the Kupferstichkabinett der Staatlichen Museen (Museum of Prints and Drawings) and, last but not least, the Library of the Max Planck Institute for the History of Science, which has focused on the upheavals of the early modern period and their consequences for the past 25 years and continues to study them today. The specimens we have collated testify to the accelerated dissemination of knowledge through the printing and circulation of books that helped to make Leonardo’s intellectual cosmos possible in the first place.

Leonardo grew up in an emergent and fascinating world of books in which contemporary knowledge circulated in new ways and could be combined from varying perspectives. He had ambitious plans to be an author himself but the traces of his wide-ranging work that he left

for posterity are provisional and often sketchy in character compared with the cohesive style and closed form of the books he aspired to but hardly ever achieved.
The exhibition shows Leonardo’s world in a process of upheaval: in media, in the transition to a new knowledge economy, in the struggle for a new understanding of the world. Which books influenced Leonardo’s intellectual cosmos? How did he work with his books? What became of his plans to write and publish his own books? Why was it so difficult for him to bring his ideas together in book form? What was lost in the transition from the *manuscript world* with its many and diverse forms—in Leonardo’s case it was often a complex weave of individual notes—to the *book world*, and what does this loss mean for our world today and its approach to new media and knowledge economies?
The exhibition resists the temptation to categorize Leonardo as a precursor, for example, of modern science and technology. Instead, it searches his intellectual cosmos for a distant mirror of our own era of radical change. What we find there, looking through Leonardo’s eyes, are not only countless unfinished projects but also the still undecided possibilities for understanding and shaping the world in one way or another. Precisely this view of his works as open and accessible offers us the opportunity to find inspiration for balances that do justice to the tensions and contradictions of our own time.

Jürgen Renn

1. □ Leonardo da Vinci. 1518. “*ecc. perché la minestra si fredda.” Codex Arundel*. British Library, London, Arundel MS 263, fol. 245r
Reprint: Pedretti. 1998. Il Codice Arundel 263. Florence: Giunti
Pen and brown ink on paper
20 x 15 cm

Image:
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This densely written sheet came from Leonardo’s later years in France. Long after his death a collector bound it into a volume that became known as the *Codex Arundel* after an owner of the works. The sheet demonstrates various geometric exercises on the transformation and determination of the length and width of different rectangles. The argumentation breaks off abruptly with a laconic “ecc.” [et cetera] indicating, as Leonardo often did, that the discourse might be continued or even that he had definite plans to do so. Leonardo explained the reason for this sudden break: *ecc. perché la minestra si fredda*. As the soup was getting cold, the studies would have to be resumed at a later date—unless, just as typically, he switched his attention to wholly different subjects.

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Leonardo's "Berlin Library"

So, drawn by my longing desire, I was eager to see the mingling of the varied and strange forms created by ingenious nature. Winding around in among the shadowy rocks, I arrived at the opening of a great cavern, in front of which I stood somewhat astonished and unknowing of such things. My back bowed, I then rested one tired hand on my knee and with my other hand shaded my narrowed eyes, often bending to look here and there and attempting to discern something, this vision forbidden me by the great darkness which was within. Remaining there awhile, there soon awoke in me two things: fear and longing; fear of the dark threatening cave, and longing to see whether some wondrous thing might be within.

Leonardo da Vinci
Codex Arundel, fol. 155r. Translation: Ronald D. Farrar

Leonardo's "Berlin Library" is the presentation of material from a lost historical book collection. Its specific focus on Berlin distinguishes it from earlier presentations over the past 150 years, which were conceived, described, and shown to audiences in different places worldwide.
The starting point for any reconstruction of Leonardo's library, which differs greatly from the libraries of contemporary artists and the private libraries of his peers, is his own writings. His numerous notebooks, the codices, contain many diverse references to books, authors, and titles. He cites, excerpts, and copies entire passages. But the primary basis for reconstructing his personal book inventory are his book lists, which vary greatly in scope:

- *Codex Trivulzianus*, fol. 2r (1487–1490)
- *Codex Atlanticus*, fol. 559r (ca. 1495)
- *Codex Madrid II*, fol. 2v–3v (ca. 1503–1504)

It is not always easy to identify the functions of these lists: Are they evidence of what he had read? Reminders for planned acquisitions? Or are they inventories in the sense of a revision? The latter is probably true, at least for the more extensive lists. Titles such as "Note on the books I'm leaving locked up in the chest," or "in the box in the monastery" seem to indicate that the lists were made in connection with a journey or moving to a new residence.
They are not catalogues in the modern sense, but rather notes and memoranda that were probably meant purely for the owner's private use (and that of his close circle). And this is exactly where the challenges for modern interpretation begin.

Approach to a "historical" library
Based on the current state of research, the first task was to transcribe Leonardo's mirror writing, to translate the individual entries as literally as possible, and to assign concrete book titles to them. It is not always possible to give a definite identification: Leonardo's note, "*cronica del mondo*" (world chronicle) could just as easily refer to Giacomo F. Foresti's *Supplementum chronicarum* or Hartmann Schedel's *Liber chronicarum*. The two titles in their respective editions from Venice in 1486 and Nuremberg in 1493 are consequently both featured in the exhibition. But even if a title is unambiguously identified, it is by no means clear which edition is meant (printed or handwritten, complete or in excerpts?). On the other hand, vague remarks like "*prediche*" (sermons) are simply impossible to identify, and individual entries are repeated, sometimes on multiple occasions.

Stocking Leonardo's Berlin Library

The material reconstruction of Leonardo's Berlin library grew out of an investigation of local library stocks and against the backdrop of specific local conditions with possible incidences of war loss or deficient states of preservation. This is why the work of choosing editions that could be exhibited—an endeavor that benefited decisively from Carlo Vecce's expertise in its early stage—sometimes led to certain deviations or even anachronisms in relation to Leonardo's "historical" library.

Extension and Contextualization

The established core (or "corpus") of Leonardo's library was thus extended for the Berlin venue to include "new additions," in other words, titles that are not definitively recorded in his book lists. This process seemed justified in the following three cases in particular:

1. Leonardo is known to have been familiar with specific works although they do not appear in the lists. Examples include Dante's *Divine Comedy* and Vitruvius' *De architectura*. The same applies to Luca Pacioli's *Divina proportione*, a work to which Leonardo himself contributed, and which is represented here as a kind of specimen copy.
2. If no appropriate edition of the identified work was available in Berlin, it was replaced by a substitute. For example, a *Miscellanea* manuscript from the 13th century, which contains, among others, texts by Euclid, Jordanus Nemorarius, Archimedes, and Alfraganus, acts as a substitute for Leonardo's note (perhaps also related to a manuscript) "*euclide vulgare c[i]oè e ꝑ[rim]i libri 3*" ("Euclid in the vernacular only the first 3 books").
3. To further understand and contextualize Leonardo's intellectual cosmos, it seemed advisable to add specific titles to the collection that establish a relation to the northern Alpine region or that did not appear in Leonardo's lifetime. One example of these somewhat anachronistic "remote loans" would be the *General trattato di numeri, et misure* by Niccolò Tartaglia, first printed in 1556. Although it appeared 37 years after Leonardo's death, it is particularly suited to illustrate the type of commercial mathematical training Leonardo would have received in his youth.

Finally, after this work came the arrangement of the selected book specimens according to the 10 sections of the exhibition, which are intended to illustrate various facets in depth and to show the gradual development of Leonardo's intellectual cosmos.

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2. □ Leonardo da Vinci. 1487–1490. *Book list (potential acquisitions?)*. *Codex Trivulzianus*. Biblioteca Trivulziana, Milan, fol. 2r

Reprint: Brizio. 1980. Il Codice di Leonardo da Vinci nella Biblioteca Trivulziana di Milano. Florence: Giunti

Pen and brown ink on paper

19.9 x 13.3 cm

Image:

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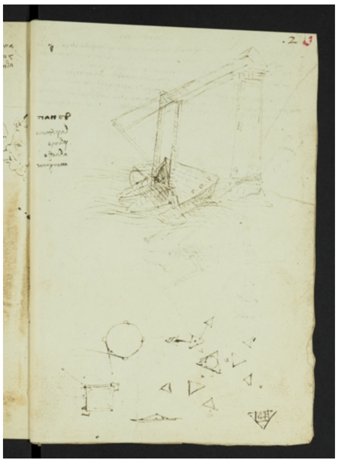

This sheet, which also contains a sketch of a siege bridge, is a list of five abbreviated book titles in Leonardo's typical mirror writing: *donato / lapidario / plinio / abacho / morgante*. They refer to the standard Latin grammar by Aelius Donatus, an unspecified *Lapidarium*, that is, a treatise on the characteristics of (precious) stones, Pliny's *Natural History* (52 □) (probably in Cristoforo Landino's Italian translation), an unspecified abacus calculation manual, and Luigi Pulci's burlesque epic about the giant Morgante. All these titles reappear in Leonardo's later booklists. If this was a list of books to be acquired, then it was actually followed through.

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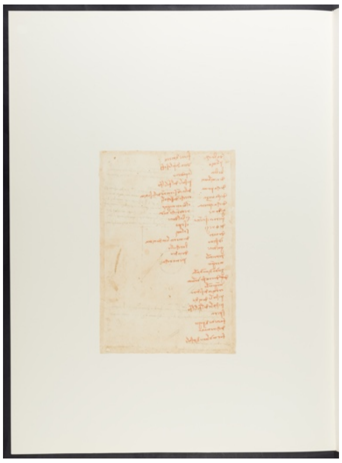
TRANSCRIPTION AND TRANSLATION

donato	*Donatus*	*abacho*	*abacus book*
lapidario	*lapidarium*	*morgante*	*Morgante*
plinio	*Pliny*		

3. □ Leonardo da Vinci. ca. 1495. *Book list*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 559r
Reprint: 1973–1975. *Il Codice Atlantico* Vol. 7. Florence: Giunti
Red chalk on paper
27.2 x 18.3 cm

Image:
00.02.03.01 - b



Around 1495, Leonardo hastily wrote this list in Milan in red chalk, his favorite medium for quick sketches. It consisted of 40 authors' names and book titles. He probably wrote it before a short trip to Florence. The list mostly consists of printed editions in Italian on topics such as history, literature, and linguistics, treatises on religion and morality, and some medical books and essays on natural philosophy.

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TRANSCRIPTION AND TRANSLATION

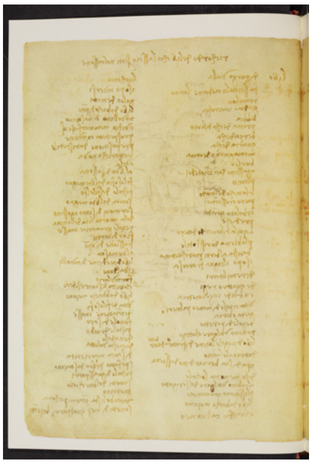
d'abacho	abacus book	*pistole del filelfo*	epistles of Filelfo
plinio	Pliny	*spera*	sphere
bibia	Bible	*facetie di pogio*	*Facetie* of Poggio
de re militari	*De re militari*	*de chiroma[n]tia*	on palmistry
decha prima	first decade (ten books)	*formulario di pistole*	formulary of epistles
decha terça	third decade (ten books)	*fiore di virtù*	*Flower of virtue*
decha quarta	fourth decade (ten books)	*vite de' filosofi*	*Vite de filosofi* (life of philosophers)l
gidone	Guidone	*lapidario*	apidarium
piero crescie[n]tio	Petrus de Crescentiis	*pistole di filelfo*	epistles of Filelfo
de' 4 regi	of the four realms	*della conservation della santità*	conservation of health

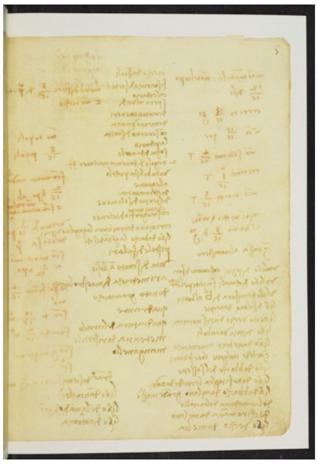
donato	Donatus	*cieco d’ascholi*	Cecco d’Ascoli
iustino	Justin	*alberto magno*	Albertus Magnus
guidone	Guidone	*rettoricha nova*	*new rhetoric*
dottrinale	doctrinal	*çibaldone*	*Zibaldone*
morgante	*Morgante*	*isopo*	Aesop
giova[n] dima[n]divilla	John Mandeville	*salmi*	psalms
de onesta voluttà	on honest pleasure	*de imortalità d’anima*	on the immortality of the soul
ma[n]ganello	*Manganello*	*burchiello*	sonnets by Burchiello
cronica d’esidero	chronicle of Saint Isidoro	*driadeo*	*Driadeo*
pistole d’ovidio	epistles of Ovid	*petrarcha*	Petrarca

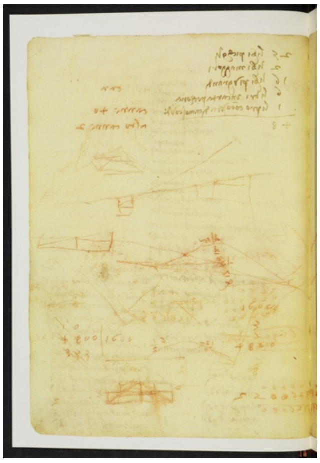
4. □ Leonardo da Vinci. ca. 1503–1504. *Book list*. *Codex Madrid II*. Biblioteca Nacional de España, Madrid, MS 8936, fol. 2v–3v

Reprint: Reti. 1974. I Codici di Madrid II. Florence: Giunti-Barbèra
Pen and brown ink on paper
21 x 14.6 cm + 21 x 14.6 cm + 21 x 14.6 cm

Images:
00.02.03.01 - c - L - (1)
00.02.03.01 - c - R
00.02.03.01 - c - L - (2)







Leonardo's most comprehensive book list was compiled in Florence between 1503 and 1504, possibly in preparation for a journey. It is divided into two parts with the heading "*Richordo de' libri ch'io lascio serrati nel cassone*" (Note on the books I'm leaving locked up in the chest," fol. 2v–3r) and "*in cassa al munistero*" ("in the box at the monastery," fol. 3r). The latter probably refers to the convent of Santa Maria Novella in Florence, where Leonardo worked on the designs for his mural of the battle of Anghiari. The list of 116 titles documents Leonardo's broadened intellectual horizon as well as numerous new additions in the sections on philosophy, technology, and natural science. A third list (fol. 3v) is arranged according to format and binding, without naming the titles. It is usually associated with Leonardo's own manuscripts. Incidentally, Leonardo miscalculated the total number of books he owned: the result should be 50, not 48.

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Findlen, Paula, and Carlo Vecce. 2019. "Leonardo's List of Books." In *Leonardo's Library. The World of a Renaissance Reader*, edited by Paula Findlen. Stanford, CA: Stanford Libraries, 184–186, (183–186).

Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 74–79.

Folio 2v

Richordo de' libri ch'io lascio serrati nel cassone	Note on the books I'm leaving locked up in the chest	Richordo de' libri ch'io lascio serrati nel cassone	Note on the books I'm leaving locked up in the chest
libro di Giorgio valla	book by Giorgio Valla	*galea de' matti*	ship of fools
fasciculu medicine latino	bundle of medicine in Latin	*libro d'abacho dipinto*	illuminated abacus book
romulion	*Romuleon*	*novellino di masuccio*	*Novellino* by Masuccio
guidone in cerusia	Guidone on surgery	*ovidio metamorfoseos*	Ovid's *Metamorphoses*
bibbia	Bible	*prospettiva comune*	common perspective
prima decha di livio	first decade (ten books) of Livy	*prepositione d'aristotile*	Aristotle's proposition
terça decha	third decade (ten books)	*rettoricha nova*	*New rhetoric*
quarta decha	fourth decade (ten books)	*atila*	*Atila*
montagnana de orina	Montagnana,on urine	*alberto di sassonia*	Albert of Saxony
burleo	Burley	*filosofia d'alberto magno*	philosophy of Albertus Magnus
agostino de civitate dei	Augustine's de civitate dei	*pistole del filelfo*	epistles of Filelfo
plinio	Pliny	*secreti d'alberto magno*	secrets of Albertus Magnus
clonica del mondo	World chronicle	*sermoni di santo agostino*	sermons by Saint Augustine
piero cressce[n]tio	Petrus de Crescentiis	*della imortalitá dell'anima*	*On the immortality of the soul*
erbolaio grande	great herbal	*regole gramatice in asse*	rules of grammar [bound] with wooden boards
prediche	sermons	*fior di virtù*	*Flower of virtue*
aquila di lionardo d'areço	Eagle of Leonardo of Arezzo	*passione di Cristo*	passion of Christ
problema d'arisstotile	problem of Aristotle	*albumasar*	Abū Ma'shar
battista alberti in architettura	Battista Alberti on architecture	*libro di medicina di cavalli*	book on medicine for horses
isopo i[n] lingua franc[i]osa	Aesop in the French language	*çibaldone*	*Zibaldone*
de re militari	*De re militari*	*formulario*	formulary
de' quattro regi	of the four realms	*clonica di santo esidero*	chronicle of Saint Isidoro
euclide in geometria	Euclid on geometry	*libro d'abbacho meçano*	a medium-sized abacus book
vita civile di matteo palmieri	*Vita civile* (civic life) by Matteo Palmieri	*vita de' filosofi*	*Vita de filosofi* (life of philosophers)
gieta e biria	Geta and Birria	*de tentatione in asse*	on temptation [bound] with wooden boards
regole di perotto	Perotti's rules	*favole d'isopo*	Aesop's fables
donato vulgare e llatino	Donatus in the vernacular and Latin	*pistole d'ovidio*	epistles of Ovid

libro di regole latine di Franc[esc]o da Urbino	book of Latin rules by Francesco of Urbino	*donadello*	Donatello (=little Donato)
dottrinale latino	Latin doctrinal	*de onesta voluttá*	on honest pleasure
opera di san bernardino da siena	work by San Bernardino of Siena	*di santa marcherita*	on Santa Margherita
della memoria locale	on local memory	*stefano prisco da sonçino*	Stefano Fieschi of Soncino
alcabitio vulgaro del serigatto	Al-Qabisi in the vernacular by Sirigatti	*pistole di guasparti*	epistles of Gasparino
plissciano gramatico	Priscian grammar	*sonetti del burchiello*	sonnets by Burchiello
libro d'abaco meçano	medium-sized abacus book	*guerrino*	Guerrin
ciriffo calvaneo	Ciriffo Calvaneo	*vocabolista in cartapechora*	dictionary in parchment
lucano	Lucan	*sonetti di messer guasparti bisconti*	sonnets by Mister Gaspare Visconti
isopo in versi	Aesop in verse		

Folio 3r

[At the top, centered]

cieco d'asscoli	Cecco d' Ascoli	*del tempio di salamone*	on the Temple of Solomon
fisonomia di scoto	physiognomy of Scot	*cosmografia di tolemeo*	*Cosmographia* of Ptolemy
calendario	calendar	*cornaçano de re militari la gug[l]ielmo de' paçi*	Cornazzano['s book] on the military subjects that Guglielmo de Pazzi has
spera mundi	sphere of the world	*libro d'abacho l'à g[i]ovan del sodo*	abacus book that Giovanni del Sodo has
de mutatione aeri	on changes in the atmosphere	*pistole di fallari*	epistles of Phalaris
de natura umana	on human nature	*vita di scanto ambrosio*	life of Saint Ambrose
conservation di sanità	conservation of health	*arimetricha di maestro luca*	arithmetic by Master Luca
lapidario	lapidarium	*donato gramaticho*	Donatus grammarian
sogni di daniello	Daniel's dreams	*quadrante*	quadrant
2 regole di domenico machaneo	2 rules of Domenico Maccagni	*quadrante del circulo*	quadrant of the circle
vocabulista piccolo	small vocabulary	*meteura d'aristotile*	meteorology by Aristotle
allegantie	on elegance	*manganello*	*Manganello*
de chiromantia	on palmistry		

[Bottom, left]

franc[esc]o da siena	Francesco of Siena	*libro dell'amandio*	book on Amandus
libro d'anticaglie	book of antiquities	*libro di notomia*	book of anatomy

[Bottom, right]

In cassa al munistero	In the box at the monastery	In cassa al munistero	In the box at the monastery
un libro d'i[n]gegni colla morte di fori	a book of ingenuities with death in front	*euclide vulgare c[i]oè e' p[rim]i libri 3*	Euclid in the vernacular, that is, the first 3 books
un libro di chavalli sc[h]içati pel	a book with sketches of horses for the cartoon (a full-scale preparatory drawing)	*libro dabbacho del sassetto*	abacus book by Francesco Sassetti
un libro da misura di B[attist]a alberti	a measuring book by Battista Alberti	*libro dove si taglia le corde da navi*	book on where to cut ships' ropes
libro di filone de acque	book by Philo on waters	*libro d'abbacho da milano grande in asse*	large abacus book from Milan [bound] with wooden boards
libretto vechio d'arissmetrica	little old arithmetic book	*dell'armadura del cavallo*	on the armor of the horse
libro di mia vocaboli	a book of my words	*de chiromantia da milano*	on the palmistry of Milan
libro da urbino matematicho	a book from the Urbino mathematician	*libro vechio d'amelia*	old book of homilies

Folio 3v

25 libri picholi	25 small books	*6 libri in cartapechora*	6 books in parchment
2 libri magg[i]ori	2 larger books	*1 libro con coverta di camoscio verde*	1 book with a green chamois cover
16 libri più grandi	16 even larger books	*48*	48

Leonardo’s Berlin Library – Index

Reference	Work	Leonardo’s Note	Translation	Source
Prologue: Old Knowledge and New Technology				
9 ☐	Ptolemy, Claudius. 14th c. *Liber de optica*. Edited and translated by Eugenius <Panormitanus>. Staatsbibliothek zu Berlin: MS lat. fol. 283			
10 ☐	Heron of Alexandria. 16th c. *Liber geoponicus*. Staatsbibliothek zu Berlin: MS Phill. 1565			
11 ☐	Aesop and Francesco del Tuppo. 1485. *Aesopus moralisatus*. Naples: Francesco del Tuppo	*isopo in versi*	Aesop in verse	*Codex Madrid II*, 2v
12 ☐	Euclid. 1482. *Elementa geometriae*. Edited by Johannes Campanus. Venice: Erhard Ratdolt	*euclide in geometria*	Euclid on geometry	*Codex Madrid II*, 2v
Roots				
15 ☐	*Biblia*. 1471. Translated by Niccolò Malermi. Venice: Wendelin von Speyer	*bibia - bibbia*	Bible	*Codex Atlanticus*, 559r *Codex Madrid II*, 2v
16 ☐	Tartaglia, Niccolò. 1556. *General trattato di numeri, et misure*. Venice: Curtio Troiano			

The Crowns of Florence				
21 ☐	Dante Alighieri. 1487. *La Comedia*. Commented by Christophorus Landinus. Brescia: Boninus de Boninis			
22 ☐	Boccaccio, Giovanni. 1370. *Decameron*. Staatsbibliothek zu Berlin: MS Ham. 90			
23 ☐	Petrarca, Francesco. 1494. *Trionfi e sonetti*. Commented by Bernardus Ilicinus and Franciscus Philelphus. Milan: Ulrich Scinzenzeller	*petrarcha*	Petrarca	*Codex Atlanticus*, 559r
Ancient Sources and New Experiences				
31 ☐	Vitruvius, Pollio. 15th c. *De architectura*. Staatsbibliothek zu Berlin: MS lat. qu. 735			
32 ☐	Alberti, Leon Battista. 1540. *De pictura praestantissimae artis et nunquam satis laudatae*. Basel: Bartholomäus Westheimer			
33 ☐	Alberti, Leon Battista. 1485. *De re aedificatoria*. Florence: Nicolaus Laurentii	*battista alberti in architettura*	Battista Albert on architecture	

34 ☐	Alberti, Leon Battista, Aesop and Aulus Gellius. 15th c. *Vita Aesopi*. Aesop: *Fabulae*. Leon Battista Alberti: *Apologi*. Aulus Gellius: *Noctes Atticae*. Staatsbibliothek zu Berlin: MS lat. oct. 171	*favole d'isopo*	Aesop's fables	*Codex Madrid II*, 2v
35 ☐	Valla, Giorgio. 1501. *De expetendis et fugiendis rebus opus*. Venice: Aldus Manutius	*libro di giorgio valla*	book by Giorgio Valla	*Codex Madrid II*, 2v
36 ☐	Crescentiis, Petrus de. 1538. *De agricultura*. Basel: Henricus Petri	*piero crescie[n]tio*	Petrus de Crescentiis	*Codex Atlanticus*, 559r *Codex Madrid II*, 2v
Cultural Challenges				
42 ☐	Perotti, Niccolò. 1490. *Rudimenta grammatices*. Venice: Bonetus Locatellus	*regole di perotto*	Perotti's rules	*Codex Madrid II*, 2v
43 ☐	Philelphus, Johannes Marius. 1486. *Epistolae*. Basel: Johann Amerbach	*pistole del filelfo*	epistles of Filelfo	*Codex Atlanticus*, 559r *Codex Madrid II*, 2v
44 ☐	Poggio Bracciolini, Gian Francesco. 1487. *Facetiarum liber*. Venice: Thomas de Blavis	*facetie di pogio*	*Facetie* of Poggio	*Codex Atlanticus*, 559r
45 ☐	Ghiberti, Bonaccorso. 15th c. *Zibaldone*. Biblioteca Nazionale Centrale di Firenze: Banco Rari 228	*çibaldone*	*Zibaldone*	*Codex Madrid II*, 2v

46 ☐	Brant, Sebastian. 1488 [1498]. *Stultifera navis* [ship of fools]. Translation by Jakob Locher. Lyon: Jacques Sacon	*galea de' matti*	ship of fools	*Codex Madrid II*, 2v
World History and Natural History				
49 ☐	Ovidius Naso, Publius. 1497. *Ovidio methamorphoseos vulgare*. Translated by Giovanni Bonsignori. Venice: Giovanni Rosso for Lucantonio Giunta	*ovidio metamorfoseos*	Ovid's *Metamorphoses*	*Codex Madrid II*, 2v
50 ☐	Lucretius Carus, Titus. 1500. *De rerum natura*. Edited by Hieronymus Avantius. Venice: Aldus Manutius			
51 ☐	Livius, Titus. 1493. *Deche di Tito Livio vulgare historiate*. Venice: Giovanni Rosso for Lucantonio Giunta	*decha prima* *decha terça* *decha quarta*	first decade (ten books) third decade (ten books) fourth decade (ten books)	*Codex Atlanticus*, 559r *Codex Madrid II*, 2v
52 ☐	Plinius Secundus, Gaius. 1481. *Historia naturale*. Translated by Christophorus Landinus. Venice: Filippo di Pietro	*plinio*	Plinius	*Codex Trivulzianus*, 2r *Codex Atlanticus*, 559r *Codex Madrid II*, 2v

53 □ 54 □	Foresti, Giacomo Filippo. 1486. *Supplementum chronicarum*. Venice: Bernardinus Benalius Schedel, Hartmann. 1493. *Liber chronicarum*. Nuremberg: Anton Koberger	*clonica del mondo*	world chronicle	*Codex Madrid II*, 2v
Challenges of Technology				
62 □	Kyeser, Konrad. 1430. *Bellifortis*. Bayerische Staatsbibliothek Munich: Clm 30150			
63 □	Valturius, Robertus. 1483. *De re militari*. Verona: Boninus de Boninis	*de re militari*	*De re militari*	*Codex Atlanticus*, 559r *Codex Madrid II*, 2v
64 □	Taccola (Mariano di Jacopo). 1432–1433. *De ingeneis III–IV*. Biblioteca Nazionale Centrale di Firenze: Palatino 766			
65 □	Taccola (Mariano di Jacopo) and Francesco di Giorgio Martini. ca. 1480. *Disegni di macchine*. Biblioteca Nazionale Centrale di Firenze: Palatino 767			
66 □	Martini, Francesco di Giorgio. 1478–1481. *Trattato di architettura e macchine*. Biblioteca Medicea Laurenziana di Firenze: *MS Ashburnham* 361	*franc[esc]o da siena*	Francesco of Siena	*Codex Madrid II*, 3r

Science as Art, Art as Science				
70 ☐	Archimedes, Johannes Campanus and Severinus Boethius. 1503. *Tetragonismus*. Edited by Luca Gaurico. Venice: Giovanni Battista Sessa			
71 ☐	Euclid, Jordanus Nemorarius, Gerardus de Brussel, Archimedes, Johannes de Tinemue, Theodosius, Geber, and Alfraganus et al. 13th c. *Miscellanea*. Staatsbibliothek zu Berlin: MS lat. qu. 510	*euclide vulgare c[i]oè e' p[rim]i libri 3*	Euclid in the vernacular, that is, the first 3 books	*Codex Madrid II*, 3r
72 ☐	Peckham, Johannes. 1482. *Prospectiva communis*. Edited by Facius Cardanus. Milan: Petrus de Corneno	*prospettiva comune*	common perspective	*Codex Madrid II*, 2v
73 ☐	Archimedes and Piero della Francesca. 1468–1492. *Opere*. Biblioteca Riccardiana di Firenze: Ricc. 106			
74 ☐	Pacioli, Luca. 1494. *Summa de arithmetica, geometria, proportioni et proportionalita*. Venice: Paganinus de Paganinis	*arimetricha di maestro luca*	arithmetic by Master Luca	*Codex Madrid II*, 3r

75 ☐	Pacioli, Luca. 1509. *Divina proportione: Opera a tutti glingegni perspicaci e curiosi necessaria*. Venice: Paganini de Paganinis			
76 ☐	Dürer, Albrecht. 1525. *Underweysung der Messung, mit dem Zirckel und Richtscheyt, in Linien, Ebenen unnd gantzen corporen*. Nuremberg: Hieronymus Andreae			
77 ☐	Ketham, Johannes de. 1500. *Fasciculus medicinae. Similitudo complexionum & elementorum*. Venice: Johannes and Gregorius de Gregoriis	*fassciculu medicine latino*	fascicles (installments) on medicine in Latin	*Codex Madrid II*, 2v
The World, Great and Small				
89 ☐	Strabo. 1510. *De situ orbis*. Translated by Guarinus Veronensis and Gregorius de Tipherno. Venice: Philippo Pincio			
90 ☐	Ptolemy, Claudius. 1486. *Cosmographia*. Edited by Nicolaus Germanus and translated by Jacobus Angelus. Ulm: Johann Reger for Justus de Albano	*cosmografia di tolomeo*	*Cosmographia* by Ptolemy	*Codex Madrid II*, 3r

91 ☐	Alexander <Aphrodisiensis>. 1548. *Alexandri Aphrodisiensis maximi peripatetici, In quatuor libros meteorologicorum Aristotelis, commentatio lucidissima, Alexandro Piccolomineo interprete*. Venice: Scotus	*meteura d'aristotile*	meteorology by Aristotle	*Codex Madrid II*, 3r
92 ☐	Sacrobosco, Johannes de. 1490. *Sphaerae mundi compendium foeliciter inchoat*. Venice: Octavianus Scotus	*spera* *spera mundi*	sphere sphere of the world	*Codex Atlanticus*, 559r *Codex Madrid II*, 3r
93 ☐	Dürer, Albrecht. 1528. *Vier Bücher von menschlicher Proportion*. Nuremberg: Hieronymus Andreae			
The Mobility of Knowledge				
99 ☐	Regiomontanus, Johannes. 1476. *Kalendarium*. Venice: Erhard Ratdolt, Bernhard Maler and Peter Löslein	*calendario*	calendar	*Codex Madrid II*, 3r
100 ☐	Apian, Petrus and Rainer Gemma Frisius. 1548. *Libro dela Cosmographia*. Antwerp: Bontius			

Leonardo’s Life and Legacy

Leonardo was a very mobile artist. He travelled widely in his lifetime and worked for a great variety of contractors and masters. His path took him from provincial Tuscany to metropolitan Florence and Milan, and finally to the courts of the pope and the king of France. His assignments and his own interests were extremely diverse. The view of the Leonardo phenomenon from posterity has always been defined by the ideas and preferences of the particular epoch. This installation is designed to give an overview of the stages of Leonardo’s life. The eight stages should be seen simply as a general frame, since the individual years cannot always be dated exactly. Each stage has an associated image to help clarify a specific aspect of Leonardo’s achievement or cast light on his intellectual and artistic legacy.

A □ - Vinci 1452–1469: Telemaco Signorini. 1896. *Vinci*. Nt 9755/2. In Gustavo Uzielli. *Ricerche intorno a Leonardo da Vinci. Edizione seconda corretta e molto ampliata*. Turin: Ermanno Loescher. (1st ed. Florence: G. Pellas, 1872)
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz
Etching
16 x 24 cm
Reproduction

Image:

10.02.03.01 - a

Leonardo was born on April 15, 1452, the illegitimate son of the notary Ser Piero da Vinci (1427–1504) and Caterina, the daughter of a local farmer. He spent his early childhood in Vinci in the house of his grandfather Antonio (died 1464), who probably gave him his first lessons. In the 19th century, the *Risorgimento*, the founding of Italy as a nation-state, inspired a growing interest in historical figures to strengthen national identity. The geologist Gustavo Uzielli (1839–1911), a follower of the freedom fighter Giuseppe Garibaldi (1807–1882), is regarded as the pioneer of scientific historical research on Leonardo's oeuvre. In 1872 he and the painter Telemaco Signorini (1835–1901) conducted on-site research in the places Leonardo lived as a child in preparation for an illustrated publication that ran to several editions. The little town in the Arno valley later became a center of Leonardo studies with its own museum and the office of the Biblioteca Leonardiana.

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Nanni, Romano, and Giuseppina Carla Romby, eds. 2001. *Nello specchio del genio. Studi storici, cultura urbana e genius loci tra Otto e Novecento nel segno di Leonardo*. Fucecchio: Edizioni dell'Erba.

B □ - Florence 1469–1482: Leonardo da Vinci. 1479. *The Hanging of Bernardo Bandini Baroncelli*

Musée Bonnat-Helleu, Bayonne. Inv.: 659r

Pen and brown ink over traces of black chalk
19.2 x 7.3 cm
Reproduction

Image:

10.02.03.01 - b

After his grandfather's death, Leonardo finally moved to Florence, where his father's connections helped him to enroll as an apprentice artist in Andrea del Verrocchio's workshop. Later, he became an independent artist. His earliest independent works include the drawing *Landscape of the Arno Valley* (1473) (18 □) and the painting *The Annunciation* (ca. 1472–1475) (17 □). *The Adoration of the Magi* from March (1481), his last Florentine commission for a while, remained unfinished.

This drawing of the hanged man Bernardo Bandini Baroncelli reveals Leonardo's curiosity and his urge to communicate daily life in the trading metropolis with drawings. The main culprits in the Pazzi conspiracy against the ruling Medici family were hanged on December 24, 1479 at a window of the Palazzo del Capitano—very close to Leonardo's house.

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C □ - Milan 1482–1500: after Leonardo da Vinci. 1497–1500. *Academia Leonardi Vinci*

Musée du Louvre, Paris, Département des Arts Graphiques, Collection Edmond de Rothschild. Inv.: 4069 LR/ Recto

Engraving

29.2 x 20.4 cm

Reproduction

Image:

10.02.03.01 - c

Leonardo moved to Milan at the beginning of the 1480s and entered the service of Ludovico Sforza (1452–1508) shortly afterwards. It was then, if not before, that he begins to systematically build up his own library (3 □). One of Leonardo's most important personal contacts during this period was the mathematician Luca Pacioli (1445–1517) (78 □). Leonardo's outstanding works of art from that time include *The Virgin of the Rocks* (first version begun in 1483) and *The Last Supper* (1494–1497). But the time-consuming project of the equestrian monument for Francesco Sforza (68 □) was never realized.

A court artist was expected to perform diverse tasks, from artworks of all kinds and ephemeral festive decorations to engineering work in military technology. The patterns called *Da Vinci's knots* are formally connected with Leonardo's decoration of the *Sala delle Asse* in the Castello Sforzesco in Milan. For the first time, the engravings of this six-part series linked the name of an artist with the term "academy." At that time, the term still meant an association of scholars with a common area of interest. Perhaps it was a sign that Leonardo had achieved fame.

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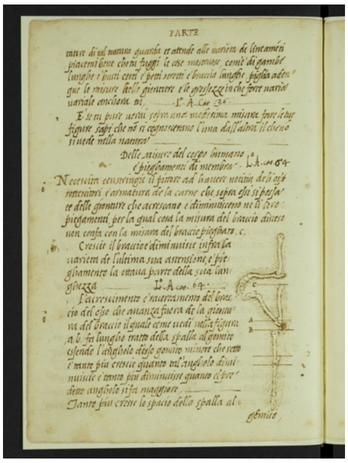
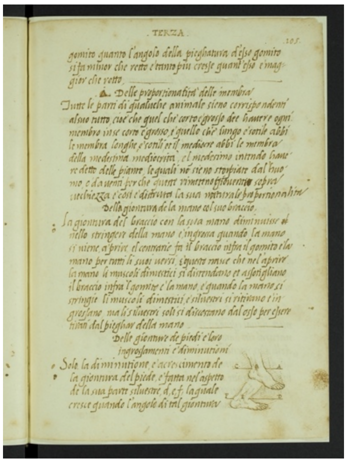
D □ - Mantua, Northern and Central Italy 1500–1502: Francesco Melzi after Leonardo da Vinci. ca. 1530–1540. *Codex Urbinas Latinus 1270 / Libro di pittura*. Biblioteca Apostolica Vaticana, Rome, fol. 104v–105r

Reprint: Pedretti. 1995. Libro di pittura: Codice Urbinate lat. 1270. Florence: Giunti
Pen and brown ink on paper
21 x 14.5 cm + 21 x 14.5 cm
Reproduction

Images:
10.02.03.01 - d - L
10.02.03.01 - d - R





With the expulsion of Ludovico Sforza by the French, Leonardo loses his noble employer and flees from Milan. A restless time ensued. After a brief stay at the court in Mantua, Leonardo goes first to Venice and Florence for a short time before finally entering the service of Cesare Borgia (1475–1507) for two years as a military architect and travelling cartographer. This work took him to many places in northern and central Italy, including Urbino, a center of art and science.

The *Libro di pittura*—now held at the Vatican Library where it is known as *Codex Urbinas Latinus 1270* after its orgin in the library of the last duke of Urbino, Francesco Maria della Rovere (1548–1630)—is a handwritten compilation of Leonardo's notes on painting that his pupil and heir Francesco Melzi (ca. 1491/92–1567) collated and organized thematically in the 1530s from the numerous manuscripts he kept in his villa. He also copied the master's drawings and diagrams that were originally intended for printing. The double page shown here comes from the third of the eight-part volume, which is devoted to "the dimensions of the human body and the movements of its limbs" (shown here are arms, wrists, and ankles).

REFERENCES

Vecce, Carlo. 2018. "Before the 'Trattato'. Philological Notes on the 'Libro di pittura' in the Codex Urbinas 1270." In *The Fabrication of Leonardo da Vinci's "Trattato della pittura." With a Scholarly Edition of the Italian "editio princeps" (1651) and an Annotated English Translation*, by Claire J. Farago, Janis C. Bell, and Carlo Vecce. Brill's Studies in Intellectual History 263. Leiden / Boston, Mass.: Brill, 71–80.

E □ - Florence 1503–1506: Giorgio Vasari. 1568. *Vita di Lionardo da Vinci – title page with portrait medallion from "Le vite de più eccellenti pittori, scultori e architettori"*

Private collection
Heritage Images / Fine Art Images / akg-images
Woodcut
25.5 x 17 cm
Reproduction

Image:

10.02.03.01 - e

At the invitation of the Florentine Republic, Leonardo returns to the city where he had started his career. He is commissioned to paint the mural of *The Battle of Anghiari* in the council chamber of the city hall, today the Palazzo Vecchio. His technical experiment with wax painting turned into a fiasco. His mammoth project for completely rechanneling the River Arno was also never executed. But the portrait of the *Mona Lisa* (1503–1504) which he also painted at that time, became his most famous work today. In the monastery of Santa Maria Novella, where he lives and works, Leonardo compiles the most comprehensive list of the books he owns (4 □).

Giorgio Vasari (1511–1574), the architect, court painter of the Medici grand dukes, and the father of modern historiography of art, influenced the popular image of Leonardo to this day with his description of the artist's life embellished with anecdotes. The biography appeared in different versions in 1550 and 1568. Vasari's viewpoint is quite ambivalent: on the one hand he admired Leonardo as the founder of the modern style of painting (*maniera moderna*), whose creations are distinguished by an almost divine grace (*grazia divina*), but on the other hand he uses Leonardo as a curiously negative example of instability, weird enthusiasms, and time-consuming interests remote from art. The portrait medallion of the bearded painter with the typical travelling cap in the 1568 edition was to consolidate the cliché of Leonardo as an oddball genius for centuries to come.

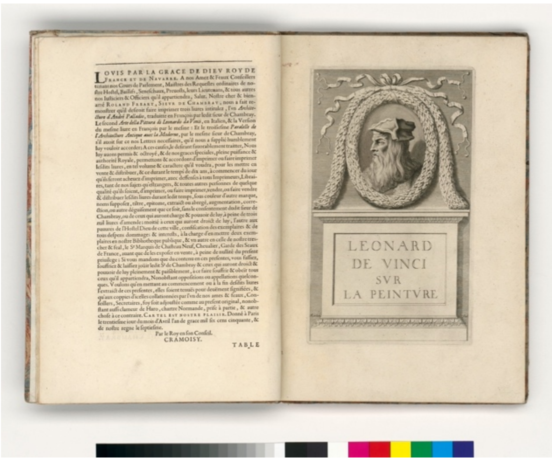
REFERENCES

Vasari, Giorgio. 2006. *Das Leben des Leonardo da Vinci. Neuübersetzt von Victoria Lorini, herausgegeben, kommentiert und eingeleitet von Sabine Feser*. Berlin: Wagenbach.

F □ - Milan 1506–1512: Roland Fréart (Roland Fréart de Chantelou Sieur de Chambray). 1651. *Traitté de la peinture / de Léonard de Vinci. Donné au public et traduit d'italien en françois par R. F. S. D. C.* Paris: Langlois

Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kupferstichkabinett. Shelfmark.: B 52
Photo: Dietmar Katz
Plate edge 29.3 x 17.5 cm / Sheet size single page 38.6 x 26.3 cm
Reproduction

Image:



[10.02.03.01 - f]

Returning to Milan, Leonardo enters the service of the French governor Charles d'Amboise (1472/73–1511) for whom he works mainly as an architect and organizer of festivities. From 1508, he also works directly for the French king Louis XII (1462–1515). Besides this, he works on designs for the horseback monument to Giangiacomo Trivulzio (1440–1518). His intensive studies of anatomy also belong to this phase. After Leonardo's death, almost 150 years passed before his treatise on painting became the first part of his writings to be printed. It is no coincidence that the treatise, which is based on a shortened version of Melzi's *Libro di pittura*, was published in Paris. By that time, the French capital had become the center of academic art theory, and the interest in Leonardo's writings in his later home of choice was correspondingly great. The engraved illustrations are based on models by Nicolas Poussin (1594–1665). The first German edition appeared in 1724 in Nuremberg with the title *Des vortreflichen Florentinischen Mahlers Lionardo da Vinci höchst-nützlicher Tractat von der Mahlerey*.

REFERENCES

Farago, Claire J., Janis C. Bell, and Carlo Vecce. 2018. *The Fabrication of Leonardo da Vinci's "Trattato della pittura." With a Scholarly Edition of the Italian "editio princeps" (1651) and an Annotated English Translation.* 2 vols. Brill's Studies in Intellectual History 263. Leiden / Boston, Mass.: Brill.

G □ - Rome 1513–1516: Leonardo da Vinci. 1513–1514. *Coin minting*. *Paris MS G*. Institut de France, Paris, fol. 43r

Reprint: Marinoni. 1989. I Manoscritti dell'Institut de France: MS G. Florence: Giunti.

Pen and brown ink on paper

14 x 10 cm

Image:

10.02.03.01 - g

After the French withdrew and the Sforzas returned to Milan, Leonardo followed his new patron Giuliano de' Medici (1479–1516), the brother of the newly elected Pope Leo X (1475–1521), to Rome. He lived in the Belvedere wing of the Vatican Palace, close to the new building of St. Peter's Basilica under construction by his friend Donato Bramante (1444–1514), and not far from the sensational frescos by Raffael (1483–1520) (14 □) and Michelangelo (1475–1564). Little is known of Leonardo's own artistic activities at that time.

Leonardo seems to have had enough leisure time in Rome to devote himself to his scientific interests. At least we can infer this from *Manuscript G* dated to this period, which contains varying topics from plant growth to metallurgy. At the city's mint (*Zecca di Roma*), he studied the technology of mintage from punching the blanks (shown below) to the mechanism of the embossing punch (above).

REFERENCES

Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 353–362.

H □ - Amboise (France) 1516/17–1519: Francesco Melzi (attributed). ca. 1515–1518.
Portrait of Leonardo da Vinci
Royal Library, Windsor. Inv.: RCIN 912726

Red chalk on paper
27.5 x 19 cm
Reproduction

Image:

10.02.03.01 - h

After losing another patron (Giuliano de' Medici) in 1516, the aging Leonardo accepted the invitation of King François I (1494–1547) to come to France. He spent the last years of his life as an honored resident at the Manoir de Cloux near Amboise. He hardly created any more paintings in this period, but probably worked on the drawings of the Deluge and scientific manuscripts. Leonardo died on May 2, 1519, but, contrary to Vasari's account and numerous portrayals by Romantic painters, not in the arms of the king.
The portrait in profile of Leonardo as an old man is attributed to his pupil and heir Francesco Melzi, who accompanied Leonardo to France. Probably the most accurate portrait of the painter, it shows him with long hair and a "philosopher's beard." This depiction, which was also the basis for the woodcut in Vasari's *Vite* and many portrayals deriving from this, helped to foster the notion of Leonardo as a wise man in possession of secret knowledge.

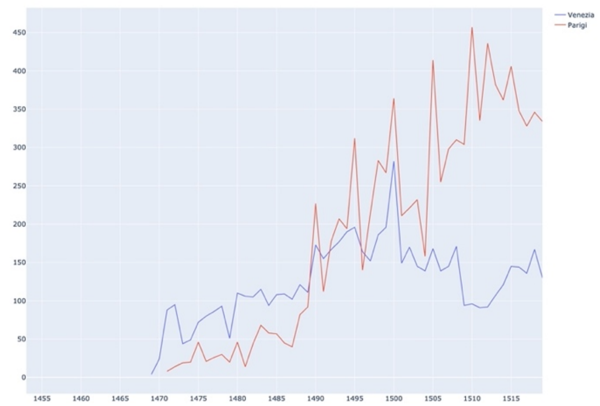
REFERENCES

Clayton, Martin. 2019. *Leonardo da Vinci. A Life in Drawing. 200 Works from the Royal Collection.* Exhibition catalogue, The Queen's Gallery, London, 24.5.–13.10.2019, The Queen's Gallery, Palace of Holyroodhouse, Edinburgh, 22.11.2019–15.2.2020. London: Royal Collection Trust, 20–21, sec. 1.

5. □ The Printing Hubs Venice and Paris

Data: USTC (https://www.ustc.ac.uk); data analysis: Andrea Ottone; visualization: Olya Nicolaeva. Max Planck Institute for the History of Science, Berlin

Image:
00.02.03.02 -a



Thanks to the Gutenberg revolution in letterpress printing, which began a few years after Leonardo's birth, the circulation of knowledge expanded on a previously unimaginable scale within just a few decades. It began with many small printing shops setting up particularly in central Europe and Italy, followed by the establishment of large production centers in these regions within less than 40 years. Multiple printing shops worked here in close proximity, sometimes cooperating but mostly under tough competitive conditions, attempting to capture the booming book market, which remained completely deregulated for a long period. Venice and Paris were established as the first of these hubs, with print runs ranging from 1,000 to 20,000 copies and hundreds of editions. Many of Leonardo's books originated from these two cities and were disseminated by a capillary distribution system (blue: Venice; red: Paris).

REFERENCES

Nuovo, Angela. 2013. *The Book Trade in the Italian Renaissance*. Leiden / Boston, Mass.: Brill.

6. □ *Printing cabinet/type cabinet. Deutsche Reichsbahn Printing Shop, Berlin, ca. 1900–1960*
Stiftung Deutsches Technikmuseum Berlin. Inv.: 1/1999/0871
Photo: SDTB / Clemens Kirchner
59 x 110.5 x 127 cm + 62.5 x 78.5 x 130 cm

Image:
00.02.03.02 - b

Around 1440, shortly before Leonardo was born, a printer from Mainz, Johannes Gensfleisch, known as Gutenberg (ca. 1400–1468), developed his principle of letterpress printing with movable type. The printed sheets were composed as required from rapidly cast individual movable type letters and reproduced using a jobbing press that derived from the design of the wine press and paper press. The basic principle of lead typesetting and the typesetter's profession hardly changed in Europe in the following 400 years. Only the printing machines were optimized and the typefaces adapted to changing tastes of the times. The transition to photomechanical typesetting and offset printing occurred in the 1970s. Type cabinets like these shown here were scrapped. Meanwhile, the wooden type cases were sold for high prices at flea markets and began a new career in home decoration as frames for displaying trinkets and collections of precious objects.

REFERENCES

Corsten, Severin, Stephan Füssel, Günther Pflug, and Friedrich Adolf Schmidt-Künsemüller, eds. 2017. *Lexikon des gesamten Buchwesens*. Online Version. Leiden / Boston, Mass.: Brill.

7. □ *Printing press. Alexanderwerk AG, Remscheid*. ca. 1900
Stiftung Deutsches Technikmuseum Berlin. Inv.: 1/2017/1163
Photo: SDTB / Clemens Kirchner
Steel, cast steel, brass
39 x 25 x 35 cm (l x w x h)

Image:
00.02.03.02 - c

This simple but highly efficient screw press uses a winding spindle or screw operated by manual force to exert pressure by clamping. Wooden wine presses and paper presses, which were the development models for the early letterpress machines, work on the same principle. So does the screw press for minting coins. The German cast iron press shown here from the *Gründerzeit* (founders' period) in the 1870s illustrates the durability and diversity of the principle. It was made by the firm Alexanderwerk AG, which owed its economic success to a popular household meat grinder. The press is not designed for printing letterpress sheets but was used (and still occasionally today) in bookbinder workshops to press the newly bound volumes.

REFERENCES

Wilkes, Walter. 1988. *Die Entwicklung der eisernen Buchdruckerpresse. Eine Dokumentation*. Darmstadt: Lehrdruckerei der Technischen Hochschule.

8. □ *Typesetter cabinet with narrow Wallau script. Druckhaus Mitte GmbH, formerly Mosse,* Berlin. ca. 1934
Stiftung Deutsches Technikmuseum Berlin. Inv.: 1/2020/0789
Photo: SDTB / Clemens Kirchner
62.5 x 27 x 5.8 cm (l x w x h)

Image:
00.02.03.02 - d

While typefaces derived from broken Gothic fonts remained in use north of the Alps for a long time, in Italy they were quickly replaced by *Antiqua,* an easily readable font with a classical look. It was adopted rather slowly in German-speaking countries. But a Gothic script revival occurred in 1910, as illustrated by this historicizing *Wallau* script. Produced in 1934 by the Offenbach Schriftgießerei (type foundry) in Klingspor as one of the last designs by the influential font designer Rudolf Koch (1876–1934), it was named after the printer Heinrich Wallau (1852–1925), one of the founding members of the Gutenberg Society in Mainz, and modelled on 14th-century round Gothic scripts. Koch, a Protestant who also made influential handwriting-based fonts for church decoration, was an enthusiastic advocate of broken script. He regarded *Fraktur* as an advanced development of Gutenberg's *Textura*, praising it as "one of the most beautiful and honorable memorials to the spirit of the German nation."

REFERENCES

Klingspor Museum, Offenbach, ed. 2020. *Wer, bitte, ist Rudolf Koch? Aus der Arbeit am Klingspor Museum zu Leben und Werk des Offenbacher Künstlers.* Ilmtal-Weinstraße: VDG.

Prologue: Old Knowledge and New Technology

Poor is the pupil who does not surpass his master.
Leonardo da Vinci
Codex Forster III, 66v

The age of Leonardo da Vinci (1452–1519) was marked by radical cultural upheavals that affected the economy of knowledge in particular. Humanist scholars, scientists, and artists extolled the knowledge of antiquity as the key reference point of the contemporary knowledge economy. At the same time, the technological development of printing opened up new possibilities for the geographical dissemination and social accessibility of knowledge. Without these profound upheavals, it would be impossible to imagine Leonardo's intellectual evolution as one of the outstanding artist-scientist-engineers of the modern age. The humanists' systematic search for ancient writings and their edition and translation offered the chance to draw on the scientific and technical achievements of the ancient world. The technology of letterpress printing made private ownership of books affordable for the first time, enabling Leonardo to build up his own library—albeit over many years. The owner's personal perspective could give new shape to the ancient and contemporary knowledge it reflected.

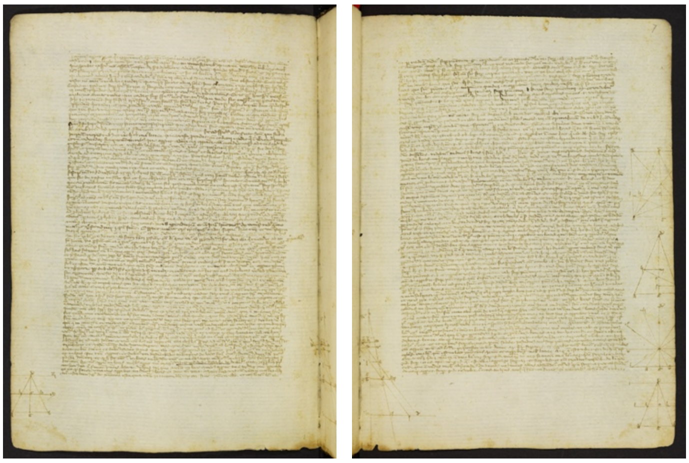
Transformation (107 □)

Leonardo’s Berlin Library: Section 1

9. □ Ptolemy, Claudius. 14th c. *Liber de optica*. Edited and translated by Eugenius <Panormitanus>

Fol. 6v–7r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS lat. fol. 283
Photo: Marvin Müller

Images:
01.01.01.01 - L
01.01.01.01 - R



This text on optics by Ptolemy (ca. 100 CE–after 160 CE) has survived in fragments in a 12th-century Latin translation based on an Arabic translation (also lost) of the Greek original. For a long period it existed only as handwritten copies like this one. The first printed edition appeared at the end of the 19th century. Ptolemy’s theory of vision was based on light rays emanating from the eyes and had a lasting influence on Arab and medieval authors. In his studies on the human eye (94 □), Leonardo worked closely with the concept of a central ray of light and the phenomenon of binocular (double lens) vision, as illustrated by the schematic marginal drawing (fol. 7, on the right).

REFERENCES

Eugenius Panormitanus. 1989. *L’Optique de Claude Ptolémée. Dans la version latine d’après l’arabe de l’émir Eugène de Sicile*. Edited by Albert Lejeune. Collection des Travaux de l’Académie Internationale d’Histoire des Sciences 31. Leiden / Boston, Mass.: Brill.

Fehrenbach, Frank. 2002. “Der oszillierende Blick. ‘Sfumato’ und die Optik des späten Leonardo.” *Zeitschrift für Kunstgeschichte* 65 (4): 522–544.

Ono, Hiroshi, Nicholas J. Wade, and Linda Lillakas. 2009. “Binocular Vision. Defining the Historical Directions.” *Perception* 38 (4): 492–507.

Smith, A. Mark, ed. 1996. *Ptolemy’s Theory of Visual Perception. An English Translation of the Optics*. Philadelphia: American Philosophical Society.

10. □ Heron of Alexandria. 16th c*. Liber geoponicus*

Fol. 206v–207r

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS Phill. 1565

Photo: Marvin Müller

Images:

01.01.01.02 - L

01.01.01.02 - R

Heron of Alexandria (around 10 CE–around 70 CE) composed numerous writings on mathematics and pneumatics, hydraulics, and mechanics (particularly machines for lifting weights). Many of his machines were designed as theatrical illusions (automata, wind-powered organs, thunder machines, etc.) to beguile the public. Others certainly had a wider use, like water pumps and a pipette-like instrument. Although Heron does not appear in Leonardo's book lists, his contribution to mechanics in the early modern period should not be overlooked. His principle of dismantling mechanical devices and reducing them to simple functions governed by the lever principle enabled subsequent authors to make the very first functional analyses of any machines, however complex.

The manuscript of *Liber Geoponicus* shown here is a compilation of different treatises in the original Greek on the topic of land surveying.

REFERENCES

Damerow, Peter, and Jürgen Renn. 2010. "The Transformation of Ancient Mechanics into a Mechanistic World View." In *Transformation antiker Wissenschaften*, edited by Georg Toepfer and Hartmut Böhme. Berlin: De Gruyter, 243–267.

11. □ Aesop and Francesco del Tuppo. 1485. *Aesopus moralisatus*. Naples: Francesco del Tuppo
Sheet 65a
Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kupferstichkabinett. Shelfmark: 2° 3115
Photo: Dietmar Katz

Image:
01.01.01.03


DE VVLPE ET AQVILA. FABVLA. XIII.
APOLOGVS.

Leonardo evidently loved reading the moralizing animal fables by the legendary Greek author Aesop. He actually owned several copies of the stories. One of the most beautiful Aesop editions was published in Naples by Francesco del Tuppo. It spotlights the high standard achieved by the art of book printing in Italy within a very short time. The text consists of Aesop's adventurous life story followed by the fables themselves in the Latin verse version, each with del Tuppo's Italian prose translation (*apologus*) and explanations of the moral and allegorical meaning. This edition also includes over 80 outstanding woodcuts, like the fable of *The Eagle and the Fox* shown here. In revenge for the theft of her cubs, the vixen sets the eagle's nest on fire. Leonardo composed similar fables himself (48 □).

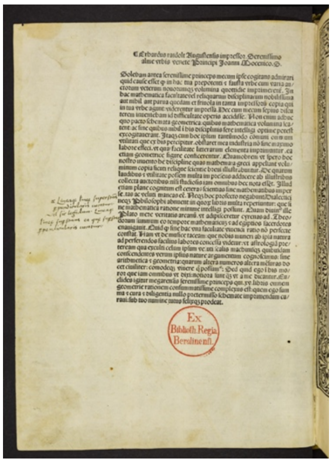
REFERENCES

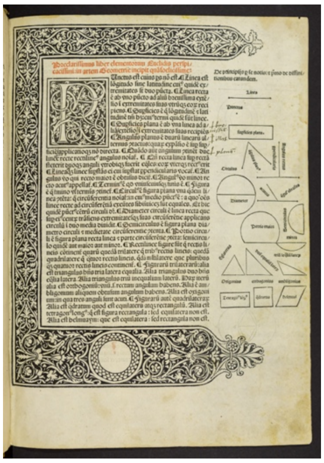
Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 96, sec. 6.8.

12. □ Euclid. 1482. *Elementa geometriae*. Edited by Johannes Campanus. Venice: Erhard Ratdolt

Sheets a1v–a2r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Inc 3781
Photo: Marvin Müller

Images:
01.01.01.04 - L
01.01.01.04 - R





The *Elements* (Greek: *Stoicheia*) by Euclid (ca. 300 BCE), was a compendium on geometry, proportion, and number theory. In the 12th century, the Englishman Adelard of Bath translated it into Latin from an Arabic version. The text was reworked in the mid-13th century by Johannes Campanus, and first printed in Venice in 1482. This ancient work has been used for over 2,000 years in countless translations and editions as a basic textbook for descriptive geometry and mathematics. Leonardo also used it as the basis for fields of knowledge like astronomy, optics, perspective, and mechanics (107 □). His colleague the painter Albrecht Dürer (76 □) from Nuremberg bought a copy of the latest edition on his trip to Venice.

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Bambach, Carmen C. 2019a. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 32–34, 460–464.

———. 2019b. *Leonardo da Vinci Rediscovered*. Vol. 4: *Scholarly Apparatus to Volumes One, Two, and Three*. 4 vols. New Haven / London: Yale University Press, 17, 22.

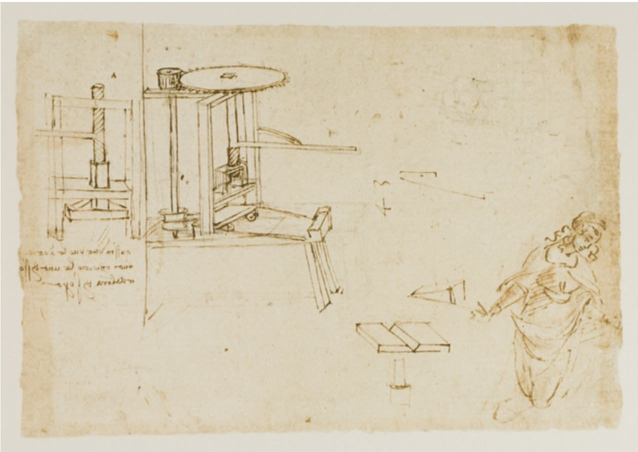
Lee, Funsoo. 2019. In *Leonardo's Library. The World of a Renaissance Reader*, edited by Paula Findlen. Stanford, CA: Stanford Libraries, 174, sec. 45.

Steck, Max. 1981. *Bibliographia Euclideana. Die Geisteslinien der Traditionen in den Editionen der "Elemente" (ΣΤΟΙΧΕΙΑ) des Euklid (um 365–300). Handschriften – Inkunabeln – Frühdrucke (16. Jahrhundert). Textkritische Editionen des 17. Jahrhunderts. Editionen der Opera minora (16.–20. Jahrhunderts)*. Arbor scientiarum. C. 1. Hildesheim: Gerstenberg.

Old Knowledge

13. □ Leonardo da Vinci. ca. 1480. *Design for a printing press*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 995r
Reprint: 1973–1975. Il Codice Atlantico Vol. 11. Florence: Giunti
Pen and brown ink over leadpoint and black chalk on paper
14.5 x 21.4 cm

Image:
01.02.02.01



Leonardo was fully aware of the potential of printing for disseminating knowledge—including his own contributions and designs—although he ended up publishing hardly anything during his lifetime. This design for mechanically optimizing the printing press dates back to his time in Florence, where the first movable type print shop was set up in 1476 in the monastery of Santa Maria Novella. Leonardo's model was probably designed to employ a semi-automatic paper feed. That he remained interested in the practical production of books later on is shown by a sheet of the *Codex Atlanticus* from 1513–1516 with his calculations for the number of movable type characters needed to print a 160-page book: 52 characters x 50 lines x 160 pages = 416,000 characters.

REFERENCES

Bambach, Carmen C. 2019a. *Leonardo da Vinci Rediscovered*. Vol. 1: *The Making of an Artist 1452–1500*. 4 vols. New Haven / London: Yale University Press, 13, 284, 296, 299.

———. 2019b. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 49–51.

Pedretti, Carlo. 1979. *The Codex Atlanticus of Leonardo da Vinci. A Catalogue of Its Newly Restored Sheets*. 2 vols. New York: Johnson, Vol. 2, VII–XII, 77, 227.

Taddei, Mario, Edoardo Zanon, and Domenico Laurenza. 2005. *Le macchine di Leonardo. Segreti e invenzioni nei Codici da Vinci*. Florence: Giunti, 226–229.

14. □ Raffaello Sanzio. ca. 1510–1511. *The School of Athens*

Stanza della Segnatura, Vatican palace, Rome
akg-images
Fresco
500 x 770 cm
Reproduction

Image:
01.02.02.02

The painter Raphael (1483–1520) depicts the representatives of ancient culture—philosophers and natural scientists—arrayed before a monumental architectural backdrop inspired by antiquity. Assembled in groups or deliberately isolated, they demonstrate the entire range of intellectual activities and discursive practices, with dialogue at the forefront. Attempts to name the individual scholars have resulted in just a few generally accepted identifications, among them Pythagoras (on the left in the foreground), Socrates with his Silenus-like appearance arguing behind him on the steps, Ptolemy on the left with the globe and crown, in front of him Euclid (or Archimedes) demonstrating a geometrical problem, and the cynic Diogenes lounging on the steps. The center of the picture is occupied by the two antagonists Plato (pointing to heaven) and Aristotle (indicating the world). Raphael is said to have given the white-bearded elder philosopher the features of Leonardo da Vinci. Finally, because the fresco was located in the Pope’s private library, the philosophers’ books and manuscripts are featured prominently.

REFERENCES

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Most, Glenn W. 1999. *Raffael und die Schule von Athen. Über das Lesen der Bilder*. Frankfurt a. M.: Fischer.

Oberhuber, Konrad. 1999. *Raffael. Das malerische Werk*. Munich: Prestel, 85–109.

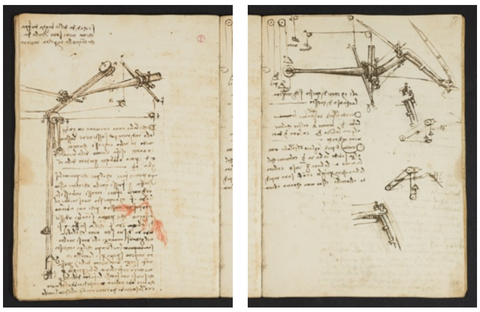
Winner, Matthias. 1993. “Stufen zur Erkenntnis in Raffaels ‘Schule von Athen’.” *Jahrbuch der Akademie der Wissenschaften in Göttingen*, 56–60.

Roots

Writing so particularly about kites must be my destiny, because in my first childhood memory, it seemed to me that, as I lay in my cradle, a kite came to me and opened my mouth with its tail, and beat the inside of my lips with its tail several times.
Leonardo da Vinci
Codex Atlanticus, fol. 186v. Translation: Elizabeth Hughes

Leonardo was the illegitimate son of the notary Ser Piero di Antonio da Vinci (1427–1504) and a farmer's daughter, Caterina. He spent his childhood in the house of his paternal grandfather Antonio (d. 1464) in the rural area of Vinci, some distance away from the metropolis of Florence. This may have encouraged his personal initiative and ultimately his independent spirit.

Aside from basic religious knowledge and familiarity with the literary classics in the Italian vernacular, the cultural education of the broad merchant and notary class at that time mainly involved a practical mastery of the arithmetic techniques needed for commercial accounting. Families usually owned small libraries of around a dozen books that were passed down through the generations. The typical collection included an edition of the Bible—often in Italian—and other religious works (collections of acts of the saints, confessionals, psalms, and sermons) as well as the vernacular classics of the literary triumvirate of Dante, Petrarch, and Boccaccio. An arithmetic book (*libro d'abaco*) was indispensable for reference and as a textbook for everyday mathematical tasks. Additionally, the head of the family consecutively recorded memorable events and recollections (*ricordanze*) in a family album. Some family members also tried their hand at writing edifying texts. Leonardo's half-brother Lorenzo (1480–1531), a wool merchant, wrote two short religious tracts. Most of the works were still handwritten codices. Book printing was still in its infancy when Leonard was young, but this would soon change rapidly, in Italy as elsewhere.



The flight of birds (114 □)

Leonardo’s Berlin Library: Section 2

15. □ *Biblia*. 1471. Translated by Niccolò Malermi. Venice: Wendelin von Speyer
Sheets 3v–4r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Inc 3630
Photo: Marvin Müller

Images:
02.01.01.01 - L
02.01.01.01 - R

In 1495, when Leonardo began working on *The Last Supper*, he noted in the *Codex Atlanticus* (fol. 288r) that he had purchased a bible for 61 soldi. It was probably the Venetian edition published in 1490 of Niccolò Malermi’s Italian translation that had first appeared in 1471. Some of its extensive woodcut illustrations may have inspired Leonardo’s own pictorial concepts. The copy of the first edition from 1471 shown here is far more luxurious. It was printed on costly parchment and then illuminated by hand. Shown here is the first page of the Book of Proverbs (“*Parabole*”), richly illustrated with figurative marginal miniatures including the famous Judgment of Solomon (top), and decorated with putti and chimaeras at the sides.

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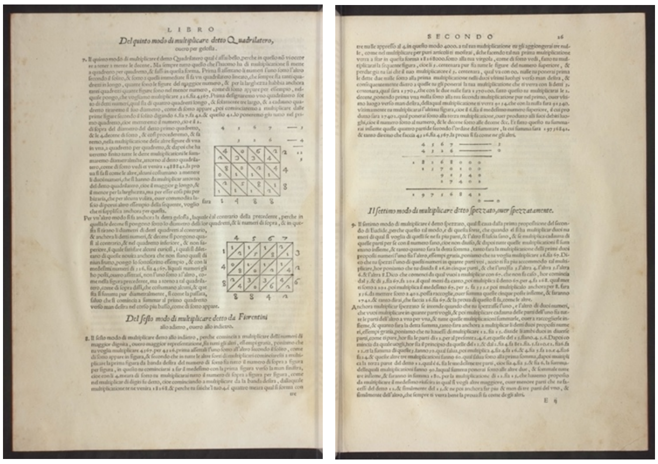
16. □ Tartaglia, Niccolò. 1556. *General trattato di numeri, et misure*. Venice: Curtio Troiano
Sheets 25v–26r
Max Planck Institute for the History of Science, Berlin. Shelfmark: 4° Rara T1935g -1, Vol. 1

Images:
02.01.01.02 - L
02.01.01.02 - R



The *General Treatise on Numbers and Measures* by Niccolò Tartaglia (ca. 1499/1500–1557) is one of the most important mathematical encyclopedias of the early modern period. It contains treatises on practical problems in arithmetic, geometry, and algebra that often occurred in daily mercantile life. Like Leonardo, the compiler, an arithmetician born in Brescia, had acquired his knowledge as an autodidact. Tartaglia even stated that he had taught himself to read and write. The open spread shown here explains, among other things, a multiplication method, which was also practiced in Florence and probably learned by Leonardo as a boy (114 □), although the textbook was produced somewhat after his lifetime. The same method (“backwards” or “from behind”) is also described by Leonardo’s friend Luca Pacioli in his arithmetic book *Summa arithmetica* (74 □).

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The Early Years

17. □ Leonardo da Vinci. ca. 1472–1475. ***The Annunciation***
Galleria degli Uffizi, Florence. Inv.: 1890 n. 1680
akg-images / Rabatti & Domingie
Oil and tempera on wood
100 x 221.5 cm
Reproduction

Image:
02.02.02.01

The young Leonardo depicted a book in the very first painting he made independently: while reading, the Virgin Mary is surprised by the archangel Gabriel, who announces she will give birth to a child. The image of Maria reading corresponds to a widespread visual tradition. The striking gesture with which the Mother of God points to a place in the manuscript text is an original idea of Leonardo’s. The manuscript is marked off according to contemporary conventions by rubrications (emphases in red script) which are not legible to the viewer but evidently refer to a verse from the book of the prophet Isaiah (7,14) in the Old Testament prophesying the birth of the Redeemer from a virgin. The picture captures the moment when Mary realizes her own predestined role in the event of salvation: the mystery of incarnation, the embodiment of the Word of God, is taking place in her womb.

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Delieuvin, Vincent, and Louis Frank, eds. 2019. *Léonard de Vinci.* Exhibition catalogue Musée du Louvre, Paris, 24.10.2019–24.2.2020. Vanves: Hazan, 72–77.

18. □ Leonardo da Vinci. August 5, 1473. *Landscape of the Arno Valley*
Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 8 P r
akg-images / De Agostini Picture Lib. / R. Bardazzi
Pen in two shades of brown ink over traces of leadpoint on paper
19.6 x 28.6 cm
Reproduction

Image:
02.02.02.02

As if from a bird's eye perspective, this wide view onto a river plain shows evidence both of natural erosion (a rock hollowed out by a waterfall) and human design (fortress architecture, grid patterns of drained swamps). The artistic novelty is that there are no active figures to be seen. It is disputed whether the young Leonardo portrayed a specific topography near his birthplace, or simply blended real recollections with imaginary visions.

What is certain, however, is the date the drawing was made. Leonardo, then aged 21, formally certified the picture at the top left in the style of a notary, with the words "on the day of Our Lady of the Snow, on August 5, 1473," in the characteristic handwriting of the Florentine mercantile class, the *mercantesca*—and he was already using mirror writing. Typical features of this fluid everyday script written without lifting the pen are a broad flow, simple elisions of the letters (ligatures), and numerous sandings. Leonardo used this script all his life. Striking calligraphic similarities suggest that he probably learned it from his grandfather Antonio.

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Merchants' Knowledge

19. □ Hans Holbein the Younger. 1532. ***Portrait of Georg Gisze***

Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Gemäldegalerie. Ident.Nr. 586
Photo: Christoph Schmidt
Oil on oak wood
97.3 x 86 cm
Reproduction

Image:
02.02.02.03

The merchant Georg Giese (1497–1562) from Danzig (now Gdańsk), worked for a time in London. This famous portrait of him by Hans Holbein (1498–1543) gives a glimpse of a typical mercantile office of the European trade network (in this case, the Hanseatic League) in the early modern period. The essential working tools of the trade included the leather-bound account book, the pewter casket for writing utensils and coins, as well as scales, a seal, signet rings, and keys. The correspondence pinned on the walls illustrates further professional connections. But the portrait goes beyond this to illustrate the social and cultural distinction of its subject, which sets him above the usual class of merchant. Status symbols like the Anatolian carpet and the Venetian vase indicate material wealth, and Latin mottos signify higher educational aspirations. To round off the picture, the cylindrical drum-watch shows Giese at the cutting edge of the latest technology.

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20. □ *Abacus (Suanpan),* early 1960s
Private loan, courtesy of Petra Paula Schwab, Leipzig
Photo: Yvonne Rischke, Kiwi-Foto
People's Republic of China
Wood, metal
28 x 14 x 2.5 cm (l x w x h)

Image:
02.02.03.01

The abacus is one of the oldest existing mechanical aids to calculation worldwide. It arrived in Europe from Mesopotamia in antiquity via trade routes in the Mediterranean, and was so widespread in Italian trade metropoles by the end of the Middle Ages that it gave its name to the primary schools and arithmetic manuals for commercial students (*scuole* or *libri d'abaco* (2 □; 3 □; 4 □)). The slide rule with beads was already known earlier in China. The *suanpan* with its classical division into two parts represents the earlier form of the Japanese *soroban*. The importance of the abacus gradually declined with the transition to written calculations after the introduction of Indo-Arabic numerals. Today, vanished from most curricula, it is merely a nostalgic symbol of initiation for the first day of school. Yet it is a durable and fail-safe calculator that is very easy to use after a bit of practice and is still used sometimes, particularly at street markets in Asia.

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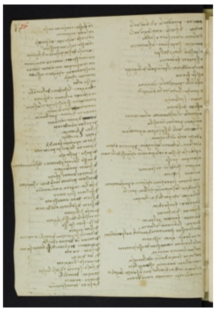
The Crowns of Florence

Think of the soldering with which the orb of Santa Maria del Fiore was welded.
Leonardo da Vinci
Paris MS G, fol. 84v. Translation: Elizabeth Hughes

In hardly any other European city of the 15th century was the level of literacy as high as in the commercial metropolis of Florence. This meant the wider population could access poetry in the Italian vernacular (*vernacolo*). Literary culture centered around the “Three Crowns of Florence”: Dante Alighieri (1265–1321), Francesco Petrarch (1304–1374), and Giovanni Boccaccio (1313–1375). This triumvirate was naturally represented in Leonardo’s library. For centuries their works set standards for literary style in Italy and beyond and fostered the development of a pre-national Italian identity based on literary language. At the same time, they reflect the encyclopedic horizon of knowledge of the time in which the Christian theological tradition is combined with a secularist worldview. Added to this is the ambition to compete with the ancient models. The openness to new experiences of nature coincides with the striving for a holistic cosmic order increasingly based on scientific knowledge. The visual arts, too, are increasingly characterized by precise observations of nature and detailed depictions, and in their own way seek to fathom the meaning and constitution of the world.

In the extremely versatile workshop of the sculptor, painter, and goldsmith Andrea del Verrocchio (1435–1488), the young Leonardo has the opportunity to acquire practical skills in a wide variety of techniques. At the same time, he internalizes the aesthetic principles of artistic design. From his enthusiastic teacher, who was himself in possession of a respectable library, the ambitious young artist also learns further forms of knowledge, which flow into the conception of the works. These include engineering knowledge and construction principles, theological-philosophical foundations and classical-literary knowledge.



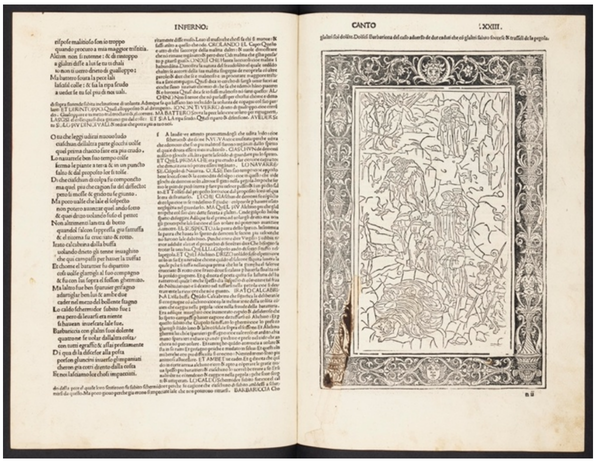
Vocabulary (108 □)

Leonardo’s Berlin Library: Section 3

21. □ Dante Alighieri. 1487. *La Comedia*. Commented by Christophorus Landinus. Brescia: Boninus de Boninis

Sheets n1b–n2a
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Inc 2812
Photo: Hagen Immel

Image:
03.01.01.02



Reading *The Divine Comedy* influenced the young Leonardo in two respects: First, linguistically the work offered an enormous vocabulary which would ultimately form the basis of Italian as a written language (108 □). Second, in terms of the history of ideas, we should not overlook the visionary character of the work, which describes the author’s wanderings in the netherworld, from Hell to Mount Purgatory and the heavenly spheres up to the vision of God in Paradise. Leonardo would have also been interested in the abundance of educational information in this work about astronomy and natural history. The Brescia edition shown here with the commentary by Cristoforo Landino has particularly impressive full-page woodcut illustrations. In canto 23 of the *Inferno*, for example, Dante and his guide Virgil meet the hypocrites. To atone for their sins they have to drag themselves onward in shining gold cowls that are, in reality, heavy as lead, until they collapse from exhaustion. The high priest Caiaphas, who was responsible for the crucifixion of Jesus Christ and is now impaled himself, serves as a human bridge for them.

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22. □ Boccaccio, Giovanni. 1370. *Decameron*
Reprint: Vittore Branca (ed.). 1975. Florence: Alinari
Fol. 47v–48r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS Ham. 90 (Reprint: HsLS CM 3002a)
Photo: Marvin Müller

Images:
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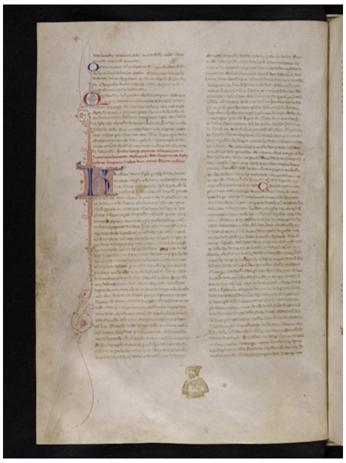
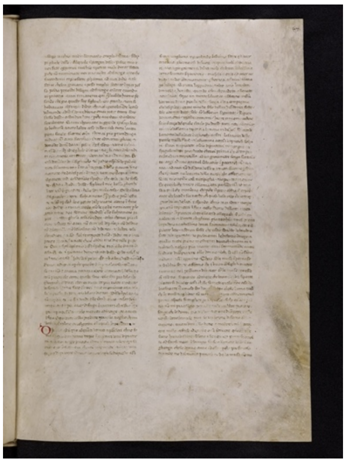
03.01.01.01 - R





Boccaccio's major work, the short story cycle *The Decameron*, is one of the most important and popular prose texts in European literary history. A group of young people from Florence takes refuge in the countryside during a plague epidemic and they amuse themselves during the 10 days there telling stories—quite often explicitly erotic tales—to each other. The manuscript in the Berlin State Library was written by Boccaccio himself and decorated with little figurative sketches in the margin. The page here shows the author making a rare comment in his own voice, defending his work against moralizing critics. He then departs from the overall narrative frame to tell a story himself. The protagonist, a sanctimonious hermit called Filippo, is pictured at the bottom of the page. To protect his naive son from sinful encounters, the hermit describes women to him like geese instead of humans. The son immediately wanted to keep a goose at home. Leonardo would probably have read *The Decameron* in his youth. His notes contain his own attempts at writing humorous novellas, ranging across the genre from didactic to coarse (48 □).

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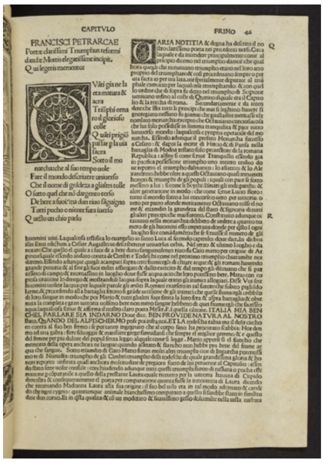
23. □ Petrarca, Francesco. 1494. Trionfi e sonetti. Commented by Bernardus Ilicinus and Franciscus Philelphus. Milan: Ulrich Scinzenzeller
Sheets 45b–46a
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3114.3, Vol. 2
Photo: Marvin Müller

Images:
[03.01.01.03 - L](03.01.01.03 - L)
[03.01.01.03 - R](03.01.01.03 - R)



While *Il Canzoniere*, a collection of poems consisting mainly of sonnets, is indisputably Petrarch's greatest work, the impact of his *Triumphs*, particularly for visual art, should not be overlooked. Using the form of a didactic poem, he describes the visionary dream of triumphal processions celebrating the victory of an allegorical figure (mortal love, chastity, death, fame, time, and eternity) over the whole of humanity. While it is true that Leonardo's early notes suggest that he was initially not an admirer of Petrarch's poetry, later notes increasingly document that he came to appreciate Petrarch's ideas about time and transience.

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Mentors

24. □ Andrea del Verrocchio and Leonardo da Vinci. ca. 1470–1475. *Baptism of Christ*
Galleria degli Uffizi, Florence. Inv.: 1890 n. 8358
akg-images / Erich Lessing
Tempera and oil on wood (poplar)
180 x 152 cm
Reproduction

Image:
03.02.02.01

The kneeling angel in profile on the left of this panel came from the workshop of Andrea del Verrocchio (1435–1488) and has traditionally been ascribed to his pupil Leonardo. Not only early written sources but also the technical painting evidence confirm this. Whereas large sections of the panel are painted in the traditional tempera technique with the paint applied in dashes, the angel, Christ's body, and the landscape are painted in oil, a technique that had only recently been adopted in Florence and which allowed completely new kinds of painterly effects. Leonardo was probably permitted to finish—and update—the painting his teacher had begun some years earlier. In his biographical account of Leonardo (Life and Legacy E □), Giorgio Vasari highlights the prodigious early talent of the young painter with an anecdote claiming that Verrocchio, overcome with frustration at his pupil's achievement, never picked up a paintbrush again.

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25. □ Giorgio Vasari. 1544. *Six Tuscan poets*
The Minneapolis Institute of Art. Shelfmark.: 71.24
Heritage Images / Fine Art Images / akg-images
Oil on wood
132 x 131 cm
Reproduction

Image:
03.02.02.02

At the center of this fictitious poets' gathering are three poets with laurel wreaths: the "Crowns of Florence." First and foremost is Dante, the *sommo poeta*, with his characteristically sharp profile. He is shown holding a volume by his ancient role model, Virgil, who appears in *The Divine Comedy* as the guide in the netherworld. Standing at Dante's right is Petrarch, also looking at Virgil's work with interest and leaning on his own collection of sonnets, *Il Canzoniere*, with a medallion of his revered Laura on the cover. Bocaccio, Dante's first biographer, is shown between the two. The triumvirate is joined on the left by Dante's close friend Guido Cavalcanti (ca. 1255–1300), and the humanists Marsilio Ficino (1433–1499) and Cristoforo Landino (1425–1498), the author of an important commentary on Dante. The terrestrial globe, the celestial globe, and the quadrant in the foreground refer to the cosmic vision in Dante's poetry. The painting was commissioned by the Florentine engineer Luca Martini (1507–1561)—who was also a key patron of Leonardo's nephew, the sculptor Pierino da Vinci (ca. 1529–1553).

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Artists’ Workshop

26. □ Leonardo da Vinci. ca. 1475. *Drapery study for a kneeling figure*
Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 420 E r
akg-images / De Agostini Picture Lib. / R. Bardazzi
Brush and gray tempera with white heightening on grounded gray canvas
16 x 16.7 cm
Reproduction

Image:
03.02.03.01 - a

Study exercises in drapery were generally common practice in Florentine artists’ workshops. Giorgio Vasari described how Leonardo made models out of plaster-soaked cloths and reproduced them with great care on the best quality canvas. Today a total of 16 such drapery studies from the Verrocchio workshop circle are known to exist. All of them are chiaroscuro works done with paintbrush on canvas—with astonishing mimetic results. At the very least, those of the best quality are attributed to the young Leonardo. Later in life, too, he set great store by the depiction of the arrangement of folds; his treatise on painting (Life and Legacy F □) devoted several pages to this topic. He warned aspiring painters not to think of the drapery as mere vanity, an end in itself. He wrote that the cloth should not appear “uninhabited”—instead, the painter’s task was to sheathe the limbs of the human body with the fabric in a pleasing fashion.

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27. □ Maso Finiguerra. ca. 1450–1460. *Painter's apprentice drawing*
Gabinetto Disegni e Stampe degli Uffizi, Florence. Shelfmark.: 115 F
bpk / Scala - Ministero Beni e Att. Culturali
Pen and brown ink, brush, brown wash over traces of black chalk and leadpoint on pink primed paper
19.4 x 12.5 cm
Reproduction

Image:
03.02.03.01 - b

In the Florentine workshop of Maso Finiguerra (1426–1464), who like Andrea del Verrocchio was a trained goldsmith, drawing also played a fundamental role in training and design. The master, however, by no means confined himself to communicating technique. He thought the activity of drawing was a subject worth portraying in its own right, and showed this in many detailed pen and ink drawings. Several workshop books document the everyday practice of apprentices and assistants like this young man who, sitting on a stool, is busily filling a small sketchbook rather like the notebooks that Leonardo would carry with him throughout his life. The motto at the bottom of this sheet was probably added later and explains the aspiration and goal of this exercise in concentration: "I want to be a good draughtsman and I want to become a good architect."

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Melli, Lorenza. 1995. *Maso Finiguerra. I disegni*. Florence: Edifir, 81, sec. 68.

28. □ Maso Finiguerra. ca. 1450–1460. *Painter's apprentice reading*

Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 66 F
bpk / Scala - Ministero Beni e Att. Culturali
Pen and brown ink over traces of black chalk
19 x 13.1 cm
Reproduction

Image:
03.02.03.01 - c

Besides practical training in drawing techniques, the workshops also offered theoretical training that included knowledge of geometry and perspective as well as the study of model collections and workshop books that were compiled in the ateliers. The sheets shown here came from these books. For the artist's apprenticeship, Leonardo also recommends the traditional approach to drawing that he was familiar with from Verrocchio's workshop. But at the same time, he wanted his treatise on painting (Life and Legacy D □) to provide apprentice painters with previously inaccessible knowledge that he had gained by his observations of nature, his scientific studies, and his many years of reading.

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Brunelleschi’s Dome

29. □ Lodovico Cardi gen. Il Cigoli. 1610. *Plan and cross-section of the dome of Florence Cathedral*
Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 7980 A
bpk / Scala - Ministero Beni e Att. Culturali
Pen and brown ink, blue wash over black chalk
46.6 x 37.9 cm
Reproduction

Image:
03.02.03.02 - a

The Florentine painter and architect Lodovico Cigoli (1559–1613) spent his later years working mainly in Rome and for the pope. This drawing is a polemical attempt to demonstrate the superiority of the dome of Florence Cathedral compared to the domes of the most prominent Roman buildings of his time: the ancient Pantheon and the modern St. Peter’s Basilica. To prove this, he used the exact plan and cross-section through the crossing of Santa Maria del Fiore together with a comparison of the profile sections of all three domes drawn exactly to scale. He showed that Filippo Brunelleschi’s masterpiece of engineering technology, erected in 1420–1436 (30 □)—visible testimony to the city of Florence’s primacy in the arts—was still an outstanding example even over a century later. It was not only the innovative rib construction with double-shell masonry that was epoch-making, but also the purpose-built machines developed by Brunelleschi, which also served Leonardo in part as a model for his machine designs.

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Fanelli, Giovanni, and Michele Fanelli. 2004. *Die Kuppel Brunelleschis. Geschichte und Zukunft eines großen Bauwerks*. Florence: Mandragora.

30. □ *View of the dome of Santa Maria del Fiore Cathedral (1420–1436),* Florence, 2003
Max Planck Institute for the History of Science, Berlin; Bibliotheca Hertziana – Max Planck Institute for Art History, Rome; Opera del Duomo, Florence
Photo: Claudia Bührig

Image:
03.02.03.02 - b

With a span of 41.98 m and a height of 86.79 m above the ground, the octagonal crossing dome of Santa Maria del Fiore dominates the skyline of Florence from far away. The city's prime landmark with its characteristic steep vaulted dome and the interplay of red-brown brick segments and contrasting white marble ribs is still regarded as the greatest brick dome ever built. It was Filippo Brunelleschi (1377–1446) who mastered the static challenge with a daring rib construction of double-layered brickwork in a herringbone pattern. He managed it without using costly wooden centering and finished the job in record time. Begun in 1420, it was consecrated by Pope Eugen IV on March 25, 1436 (The Day of the Annunciation of the Virgin). But the lantern topped by the gilded copper sphere made by Andrea del Verrocchio was not finally completed until 1471. Verrocchio's former collaborator Leonardo would still remember it in old age (*Paris MS G*, fol. 84v).

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Markschies, Alexander. 2011. *Brunelleschi*. Munich: C.H. Beck, 45–60.

Ancient Sources and New Experiences

By nature, all good humans have a thirst for knowledge
Leonardo da Vinci
Codex Atlanticus, fol. 327v. Translation: Elizabeth Hughes

In the 15th century, scholars throughout Europe, especially in Italy, sought to raise knowledge of and familiarity with authors from ancient Greece and Rome to a new level. The goal of these humanists was to collect textual sources systematically from widely diverse fields of knowledge and make them accessible through commentaries, translations, and soon through printed editions as well. Encyclopedias such as those by the philologist and mathematician Giorgio Valla (ca. 1447–1499) made previously rare handwritten treatises generally available.

Florence was the first center of this movement, which was celebrated as the rebirth (*Rinascita* or *Rinascimento* in Italian, *Renaissance* in French) of ancient culture. The ideal of antiquity rapidly penetrated and inspired every cultural area, from the literature on architecture to the visual arts. Parallel to this, the study of ancient traditions also promised resources for solving technical and scientific problems and tasks of contemporary life. Ancient natural scientists such as the Greek mathematicians Archimedes (ca. 287–212 BCE), Ptolemy (ca. 100–160 CE), and Euclid (ca. 300 BCE) were important authorities whose extant works formed a fixed canon. Their achievements also inspired Renaissance scholars in their own research and further observations.

Another canonical work is the *Ten Books on Architecture* by the Roman architect and engineer Vitruvius (ca. 70 BCE–ca. 15 CE). Its impact can hardly be overestimated and Leonardo da Vinci naturally owned an edition.

A contemporary counterpart are the writings of the philologist, master builder, and art theorist Leon Battista Alberti (1404–1472). His architectural designs, like those for the façade of Santa Maria Novella in Florence, are considered incunabula of Renaissance architecture, while his writings on the genres of architecture, painting, and sculpture laid down the first theoretical basis for the new forms of design. The humanist Alberti was regarded by his contemporaries as a shining example of universal education. He was an inspiration for Leonardo, too, not least for the latter's own theoretical writings on painting.

Problem-solving (111)

Leonardo’s Berlin Library: Section 4

31. □ Vitruvius, Pollio. 15th c. *De architectura*
Fol. 126v–127r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS lat. qu. 735
Photo: Marvin Müller

Images:
04.01.01.03 - L
04.01.01.03 - R

The *Ten Books on Architecture* by the Roman architect and engineer Vitruvius make up the only surviving architectural treatise from antiquity. It was regarded as canonical in the early modern period and until well into the 18th century. Besides covering the architect’s actual fields of work, the compilation contains many treatises from other areas of knowledge including water supply, astronomy, chronometry, and machine construction. Proportion theory and anthropometry play a particularly important role. Many artists—not least Leonardo da Vinci— have visually represented Vitruvius’ concept of the ideal human inscribed both in a circle and a square (*Homo Vitruvianus*) (40 □).

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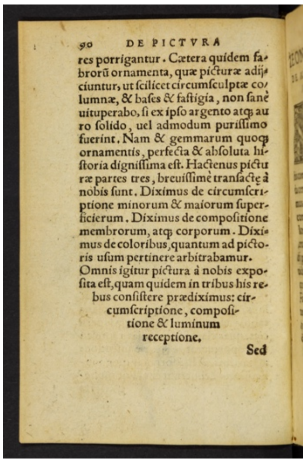
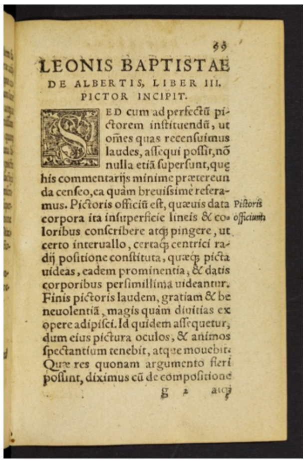
32. □ Alberti, Leon Battista. 1540. *De pictura … libri tres*. Basel: Bartholomäus Westheimer

Sheets [90]–99
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Nu 2186 R
Photo: Marvin Müller

Images:
04.01.01.04 - L
04.01.01.04 - R


90 DE PICTVRA
res porrigantur. Cætera quidem fabrorũ ornamenta, quæ picturæ adijciuntur, ut ſcilicet circumſculptæ columnæ, & baſes & faſtigia, non ſanè uituperabo, ſi ex ipſo argento atq; auro ſolido, uel admodum puriſſimo fuerint. Nam & gemmarum quoq; ornamentis, perfecta & abſoluta hiſtoria digniſſima eſt. Hactenus picturæ partes tres, breuiſſimè tranſactę à nobis ſunt. Diximus de circumſcriptione minorum & maiorum ſuperficierum. Diximus de compoſitione membrorum, atq; corporum. Diximus de coloribus, quantum ad pictoris uſum pertinere arbitrabamur. Omnis igitur pictura à nobis expoſita eſt, quam quidem in tribus his rebus conſiſtere prædiximus: circumſcriptione, compoſitione & luminum receptione.
Sed


99
LEONIS BAPTISTAE
DE ALBERTIS, LIBER III.
PICTOR INCIPIT.
SED cum ad perfectũ pictorem inſtituendũ, ut om̃es quas recenſuimus laudes, aſſequi poſſit, nõ nulla etiã ſuperſunt, quę his commentarijs minime prætereunda cenſeo, ea quàm breuiſsimè referamus. Pictoris officiũ eſt, quæuis data corpora ita inſuperficie lineis & coloribus conſcribere atq; pingere, ut certo interuallo, certaq; centrici radij poſitione conſtituta, quæq; picta uideas, eadem prominentia, & datis corporibus perſimillima uideantur. Finis pictoris laudem, gratiam & beneuolentiã, magis quàm diuitias ex opere adipiſci. Id quidem aſſequetur, dum eius pictura oculos, & animos ſpectantium tenebit, atque mouebit. Quæ res quonam argumento fieri poſſint, diximus cũ de compoſitione Pistoris officium
g 2 atq;

De pictura by Leon Battista Alberti (1404–1472) is one of the most important sources for Leonardo’s notes on painting that were later compiled as the *Libro di pittura* (*The Book on Painting*) (Life and Legacy D □). As Lucia Bertolini recently confirmed, Leonardo propagated the renewal of painting on the basis of mathematics in his treatise contained in three books first written in the Italian vernacular and then translated into Latin by Alberti himself.

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Sinisgalli, Rocco. 2006. *Il nuovo “De pictura” di Leon Battista Alberti. The New “De pictura” of Leon Battista Alberti*. Collana di Studi sul Rinascimento 7. Rome: Kappa.

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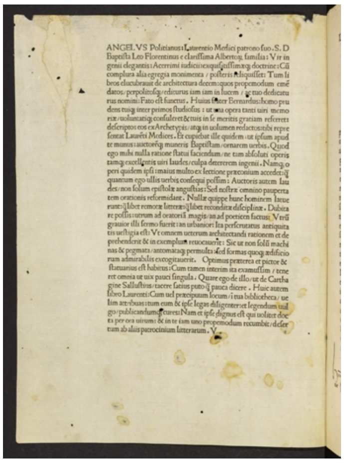
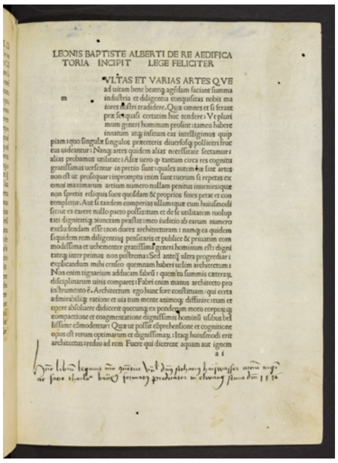
33. □ Alberti, Leon Battista. 1485. *De re aedificatoria*. Florence: Nicolaus Laurentii
Sheets 1v–2r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 2885
Photo: Marvin Müller

Images:
04.01.01.05 - L
04.01.01.05 - R





The manuscript *De re aedificatoria* by Leon Battista Alberti was presented to Pope Nicholas V in 1452, the year Leonardo da Vinci was born. It was printed for the first time in 1485, while the first printed edition of Vitruvius' *De architectura* appeared in the following year. In his book lists, Leonardo referred to Alberti's *De re aedificatoria* as *batista alberti in architettura* (3 □). Alberti's treatise on architecture which, like that of Vitruvius, consists of ten books, profoundly influenced architects and their clients in the Renaissance. *De re aedificatoria* forms a trilogy together with two other works by Alberti: *De pictura* and *De statua*. Alberti, who was seen as epitomizing the Renaissance humanist educational ideal, was deeply revered by Leonardo and his contemporaries.

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34. □ Alberti, Leon Battista, Aesop, and Aulus Gellius. 15th c. *Vita Aesopi. Aesop:* Fabulae*.* *Leon Battista Alberti:* Apologi*.* *Aulus Gellius:* Noctes Atticae

Fol. 18v–19r

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS lat. oct. 171

Photo: Marvin Müller

Images:

[04.01.01.01 - L](04.01.01.01 - L)

[04.01.01.01 - R](04.01.01.01 - R)

This composite manuscript from the second half of the 15th century contains the (incomplete) life story and fables of Aesop in a Latin prose version. It includes the fable of *The Eagle and the Fox* (11 □) along with a partly incomplete copy of the *Apologi centum*, an extensive collection of fables by Leon Battista Alberti that originally numbered 100 texts. At a time when the “original” Greek Aesop was being rediscovered and translated, the Italian humanist Alberti renewed the ancient genre by liberating it from its largely didactic textbook function and elevating it to an artistic literary form for educated adults. His 100 *Apologi*, which he claimed to have written in just nine days in December 1437, are distinguished by the great stylistic elegance of the Latin and their meticulous brevity. Inspired by Alberti’s *Apologi*, Leonardo composed around 50 of his own, similarly trenchant fables, but in his native Italian (48 □).

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35. □ Valla, Giorgio. 1501. *De expetendis et fugiendis rebus opus*. Venice: Aldus Manutius
Sheets u5v–u6r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Ald. Ren. 30,8, Vol. 1
Photo: Marvin Müller

Images:
04.01.01.02 - L
04.01.01.02 - R

De expetendis et fugiendis rebus by Giorgio Valla (1447–1499), a humanist from Piacenza, is an extensive composite manuscript dealing with the arts of the *Quadrivium* (arithmetic, geometry (111 □), music, astronomy) as well as natural philosophy, medicine, and the humanities. Leonardo found rare texts by Archimedes in this collection, as well as treatises on topics that interested him in the years after 1500. Among them are the pages shown here with the analysis of mean proportions, the precondition for solving the so-called Delian problem by the doubling of the cube according to Archimedes' method of exhaustion, which was passed down in a text by Johannes Philoponos (ca. 490–ca. 574 CE).

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———. 2019b. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 111, 264–278, 377–382.

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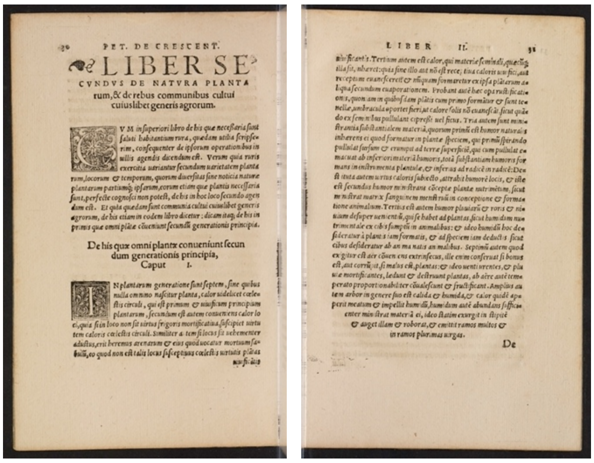
36. □ Crescentiis, Petrus de. 1538. *De agricultura*. Basel: Henricus Petri
Sheets 30–31
Max Planck Institute for the History of Science, Berlin. Shelfmark: 4° Rara C919d

Images:
04.01.01.06 - L
04.01.01.06 - R



This book on agriculture by the Bolognese author Piero de Crescenzi (ca. 1233–1320) was one of the most popular manuals of its kind in the early modern period. Written in Latin at the beginning of the 14th century, the first printed edition, titled *Ruralia commoda*, appeared in 1471. An Italian edition is recorded in Leonardo's book lists as *"libro di piero cresscenzo."* Beginning with ancient works on agriculture like *De re rustica* by Lucius Columella (died ca. 70 CE), Crescenzi gave practical advice on every aspect of the agricultural system and rounded off with a review of the year for the work needed in the fields. Leonardo used the text as a reference source for his botanical research (such as studies on tree growth (55 □)), and for his designs for irrigation systems or ideal facilities for grain storage.

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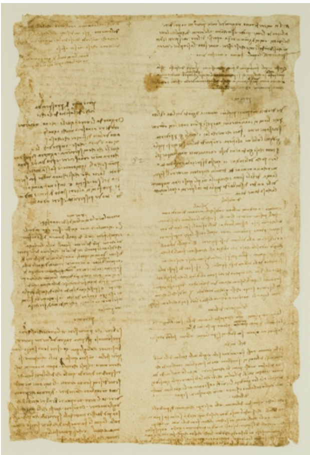
Foundations

37. □ Leonardo da Vinci. ca. 1490. *Self-description as "homo sanza lettere*." *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 327v
Reprint: 1973–1975. Il Codice Atlantico Vol. 4. Florence: Giunti
Pen and brown ink on paper
30.7 x 20.7 cm

Image:
04.02.02.01



This passage tells us about Leonardo's intellectual self-image and his desire for social recognition. He begins by defending himself as an autodidact against the prejudice of certain "arrogant" people who see him as a man without knowledge and power of expression ("*sanza lettere*") because of his meager (classical) education. While openly addressing his lack of formal study, he immediately counters with a deliberate scholarly reference to classical Roman history. He concludes proudly that he is not guided by secondhand knowledge from books but—like everyone who knew quite well how to write—solely by his own experience (*sperienzia*).

REFERENCES

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TRANSCRIPTION AND TRANSLATION

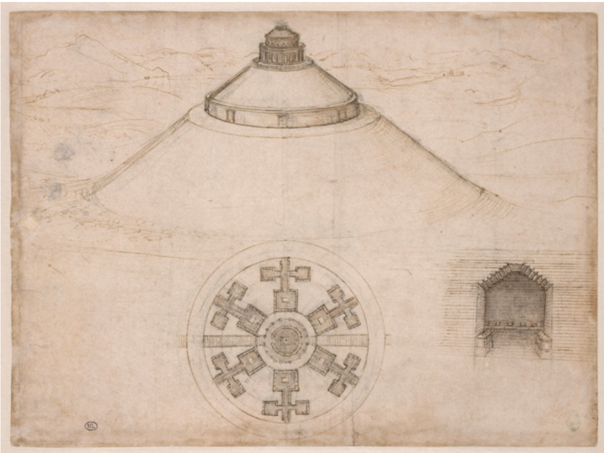
"I am fully aware that the fact of my not being a lettered man may cause certain arrogant persons to think that they may with reason censure me, alleging that I am a man without letters [*homo sanza lettere*]. Foolish folk! Do they not know that I may retort by saying, as did Marius to the Roman patricians: 'They who themselves go adorned in the labour of others will not permit me my own?' [the patricians have no merit other than that of their ancestors]. They will say that, because of my lack of book learning, I cannot properly express what I desire to expound upon. Do they know that my subjects are based on experience rather than on the words of others? And experience has been the mistress of those who wrote well. And so, as mistress, I will acknowledge her and, in every case, I will give her as evidence."

Vasari, Giorgio. 2006. *Das Leben des Leonardo da Vinci*. New translation by Victoria Lorini, edited, commented, and introduced by Sabine Feser. Berlin: Wagenbach, 52, cited after Chastel 1990, 126.

38. □ Leonardo da Vinci. 1508. *Design for an Etruscan tomb*
Musée du Louvre, Paris, Département des Arts Graphiques. Inv.: 2386 r

Pen and brown ink, wash over black chalk
19.9 x 26.7 cm
Reproduction

Image:
04.02.02.02



On January 29, 1507 several Etruscan burial chambers were discovered during work in a vineyard near Castellina in Chianti. Given the contemporary interest in rediscovering the rather obscure Etruscan culture as a homegrown "pre-Roman" heritage, the find drew the attention of various Florentine scholars. In this cleanly executed presentation drawing, Leonardo, who stayed in Florence for a while in 1508, depicts the characteristic tumulus before a broad landscape panorama and gives glimpses into the burial chambers with their authentic corbel vault, although he somewhat exaggerates the number of chambers in the ground plan. The crowning circular temple is an addition of his own imagining. It was inspired by the *Tempietto,* the recently erected commemorative tomb in Rome designed by his contemporary Bramante.

REFERENCES

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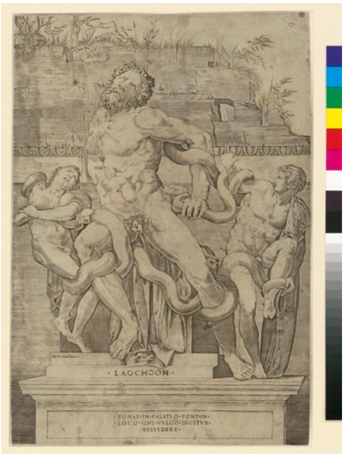
39. □ Marco Dente da Ravenna. ca. 1520–1523. *Laocoön*

Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kupferstichkabinett. Inv.: 917-24
Photo: Dietmar Katz
Engraving
48 x 32.3 cm
Reproduction

Image:
04.02.02.04



Two outstanding witnesses, the artist Michelangelo Buonarroti and the papal architect Giuliano da Sangallo, were present when a sensational archeological find of sculptures was excavated in a vineyard on the Esquiline Hill in Rome on January 14, 1506. It was quickly identified as the Laocoön Group of figures extolled by Pliny in his *Naturalis Historia* (XXXVI, 37) (52 □). The deadly struggle of the Trojan priest and his sons against two snakes is depicted with extraordinary pathos. Pope Julius II himself secured the exemplary masterpiece for his antiquity collection in the Vatican. It occupied a place of honor in the newly built statue court of the Belvedere, where Leonardo was later able to study it. This engraving by Marco Dente (ca. 1490–1527) is one of the earliest, showing the group without the later additions. While the inscription on the engraving already names the installation site, the ruins of an ancient wall in the background recall the original context of the find.

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Muth, Susanne, ed. 2017. *Laokoon. Auf der Suche nach einem Meisterwerk.* Exhibition catalogue Winckelmann-Institut der Humboldt-Universität zu Berlin, 19.10.2016–31.7.2018. Rahden, Westf.: VML Verlag Marie Leidorf.

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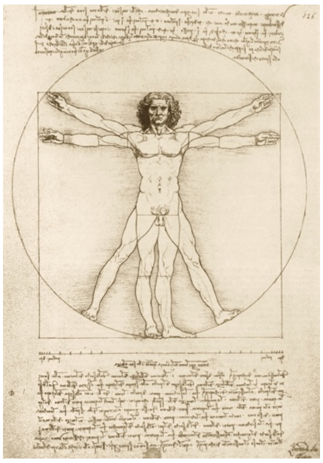
Proportions of the Ancients

40. □ Leonardo da Vinci. ca. 1490. *The Vitruvian Man (Homo Vitruvianus)*
Gallerie dell'Accademia, Venice. Inv.: 228
akg-images
Pen and brown ink with traces of wash over metalpoint, on paper
34.4 x 24.5 cm
Reproduction

Image:
04.02.02.03



Leonardo's proportional figure illustrated the theory of the ancient Roman architectural theorist Vitruvius, which states that the well-formed human being (*homo bene figuratus*), standing upright, fits into the perfect geometrical forms of both a square and a circle. Unlike the visual interpretation of this by other artists (Francesco di Giorgio Martini, Mariano di Jacopo Taccola), in Leonardo's version the center of the circle (the navel) does not correspond to the central axis of the square (the groin), which results in a more convincing aesthetic representation.

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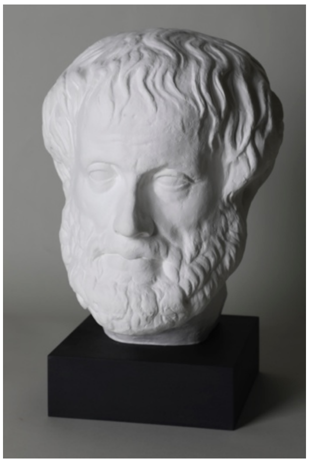
Zöllner, Frank. 1987. *Vitruvs Proportionsfigur. Quellenkritische Studien zur Kunstliteratur im 15. und 16. Jahrhundert*. Worms: Wernersche Verlagsgesellschaft.

41. □ *Head of Aristotle, Roman copy from 1st–2nd century CE after a Greek original from 4th c. BCE*

Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Abguss-Sammlung Antiker Plastik der Freien Universität Berlin
37 cm (h)
Plaster cast

Image:
04.02.03.01



Like the writings of ancient authors, their portraits were handed down through copies and translations into other media. This portrait of the Greek philosopher Aristotle (384–322 BCE) is a plaster cast copy of the marble head that is kept today in the Kunsthistorisches Museum in Vienna (Inv. I 246). That, in turn, is a Roman copy from the early imperial age based on a Greek bronze original. The head, one of 20 known existing replicas, was linked to a statue by the sculptor Lysippos (ca. 390–ca. 306 BCE), which was commissioned by Aristotle's most famous pupil, Alexander the Great. It is notable for its clearly individualized physiognomy, with the wrinkles of age, the furrowed "thinker's brow," and thinning hair. The beard is typical for philosophers' portraits—and is likewise a feature of every Leonardo portrait (Life and Legacy H □). His library is known to have included several texts by the Greek philosopher (4 □; 91 □)

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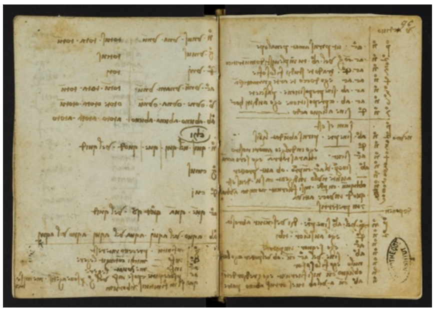
Cultural Challenges

I am fully aware that the fact of my not being a lettered man may cause certain arrogant persons to think that they may with reason censure me, alleging that I am a man without letters. Foolish folk!
Leonardo da Vinci
Codex Atlanticus, fol. 327v. Translation: Barbara Fanini

Leonardo would have had little difficulty acquiring the religious and literary traditions of his period in the vernacular. This was to a certain extent expected as part of the intellectual socialization of a son from the Florentine bourgeoisie and a young artist who had been trained in one of the city's most prestigious workshops. But it was far more difficult for him to explore fields of knowledge with different social connotations. In urban and courtly societies, access to high culture was reserved for those who had completed traditional studies in the form of a regulated curriculum. A command of Latin was imperative for acquiring the scientific and literary culture of antiquity. Leonardo became aware of his deficits, particularly in the cultivated surroundings of the Milanese court, and made great efforts to educate himself accordingly. He taught himself Latin and tried to master the current literary forms for conversation and written correspondence, all the while learning new technical and literary expressions to expand his vocabulary. Devising clever artistic subjects, such as those popular in the courtly milieu, also required a degree of familiarity with the subjects of classical education. Leonardo's library reveals the growing diversity of fields of interest and work. This intellectual evolution, always closely linked with his own career, was facilitated not least by printing, which was rapidly gaining importance and made written works cheaper and more easily available.



Rules of grammar (112)

Leonardo’s Berlin Library: Section 5

42. □ Perotti, Niccolò. 1490. *Rudimenta grammatices*. Venice: Bonetus Locatellus
Sheets 1v–2r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 8° Inc 4167.20
Photo: Marvin Müller

Images:
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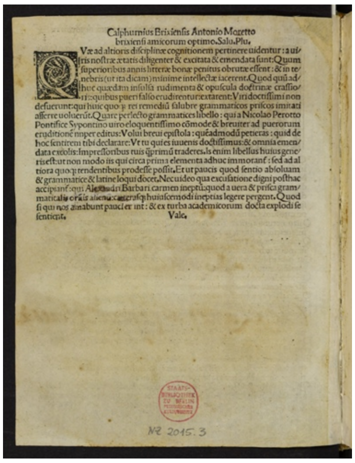

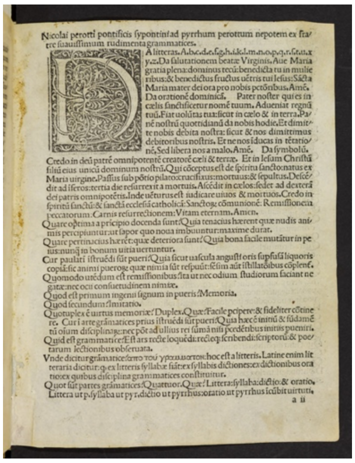

The *Rudimenta Grammatices* by the humanist Niccolò Perotti (ca. 1430–1480) was one of the 15th century’s most widely read grammars. Leonardo used it to teach himself Latin in Milan in the 1490s. Grammar exercises from the years 1494 and 1498 can be found in his *MSS H*, *I* (112 □), *Codices Forster II* and *Arundel,* and on numerous sheets in the Royal Library in Windsor.

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43. □ Philelphus, Johannes Marius. 1486. *Epistolae*. Basel: Johann Amerbach

Sheets 5v–6r

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 434.3a (Wgdr. 22)

Photo: Marvin Müller

Images:

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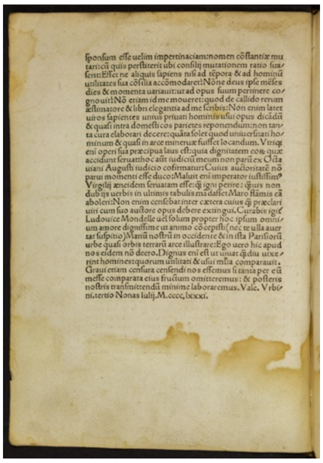

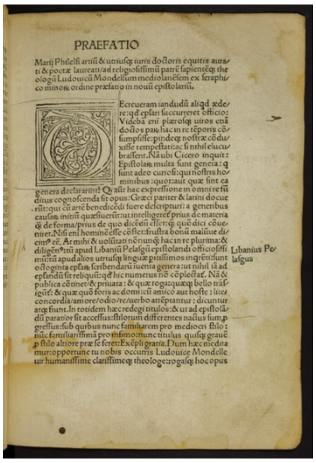

PRAEFATIO

The treatise by Giovanni Mario Filelfo (1426–1480) on the art of writing letters appears as *pistole del filelfo* in several of Leonardo's book lists (3 □; 4 □). The work is divided into a theoretical part and a practical collection of sample letters for a wide variety of occasions, from petitions and business letters to birth announcements, condolences, and "serious" declarations of love. Each of these is written in a different style, from familiar to solemn, and refers to the respective, mostly illustrious authors of the examples. Although they are written solely in Latin, the collection was certainly of practical value for Leonardo. For example, its list of standard forms of address (*epitheta*) for people of widely different ranks, from the pope to farmers and artisans, was a useful guide.

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Pignatti, Franco. 1997. "Filelfo, Giovanni Mario." In *Dizionario biografico degli italiani*. Vol. 47. Rome: Istituto della Enciclopedia Italiana.

44. □ Poggio Bracciolini, Gian Francesco. 1487. *Facetiarum liber*. Venice: Thomas de Blavis
Sheets 1v–2r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 8° Inc 3809.15
Photo: Marvin Müller

Image:
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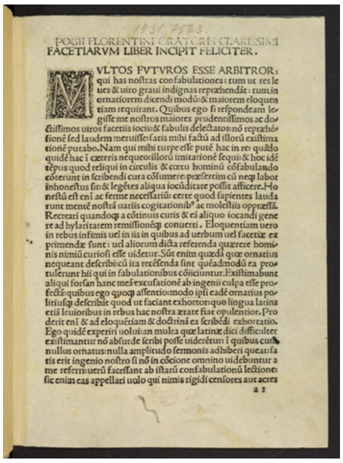
POGII FLORENTINI ORATORIS CLARISSIMI FACETIARVM LIBER INCIPIT FELICITER.

MVLTOS FVTVROS ESSE ARBITROR:

The humanist Poggio Bracciolini (1380–1459), renowned for his discoveries of ancient codices and texts like Lucretius' *De rerum natura* (50 □), also wrote a popular *Liber facetiarum*, a collection of coarse, droll stories about the customs of his time. Leonardo probably read the work in the Italian translation and seems generally to have enjoyed the literary genres of satire and the short story. The text was also used in the collection of lexical lists in the *Codex Trivulzianus* (108 □).

REFERENCES

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45. □ Ghiberti, Bonaccorso. 15th c. *Zibaldone*. Biblioteca Nazionale Centrale di Firenze: Banco Rari 228
Fol. 198v–199r
Facsimile
Museo Galileo, Florence

Images
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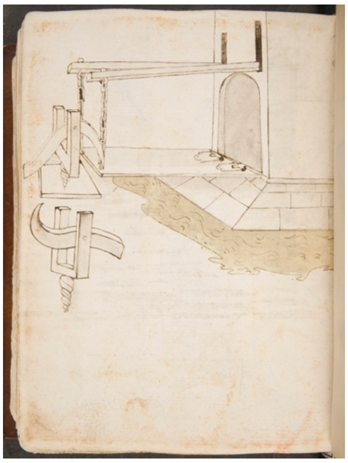

Bonaccorso Ghiberti (1451–1516), the grandson and heir of the famous Lorenzo Ghiberti, continued running his grandfather's sculpture workshop as a foundry. The *Zibaldone* (miscellany) he compiled is a notebook and sketchbook on the topics of architecture, the art of engineering, mathematics, and practical geometry. Aside from remarks inspired by Vitruvius' *De architectura* and Valturio's *De re militari* it includes numerous sketches of the machines that Filippo Brunelleschi developed for the construction of the dome of Florence Cathedral (30 □). The manuscript may have provided the young Leonardo with access to Brunelleschi's inventions and other technical equipment of the time (compare the design for a siege machine with a covered bridge (121 □)).

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46. □ Brant, Sebastian. 1488 [1498]. *Stultifera navis [Ship of fools]*. Translated by Jakob Locher. Lyon: Jacques Sacon

Sheet 1r

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 4716.40

Photo: Hagen Immel

Image:

05.01.01.04

The *Narrenschiff* (*Ship of fools)* by the Basel humanist Sebastian Brant (1457/58–1521), one of the most widely circulated books in the early modern period, was first published in Basel in 1494. The Latin translation by Jacob Locher followed just three years later and quickly became an international bestseller. Leonardo, who is known to have enjoyed satirical literature, owned a copy himself. The moralistic satire presents different follies of the time in over 100 chapters. Its success was certainly due in part to its abundance of woodcut illustrations, some of which were attributed to the young Albrecht Dürer. The illustration here is from the beginning of the book and shows the journey of the ship of fools to the kingdom of Narragonia.

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Leonardo’s Desk

47-a. □ Leonardo da Vinci. 1508. *First draft letter*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1037v
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Pen and brown ink on paper
28.1 x 21.3 cm

Image:
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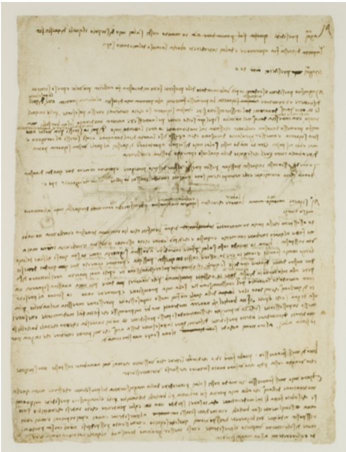

47-b. □ Leonardo da Vinci. 1508. *Second draft letter*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 872r
Reprint: 1973–1975. Il Codice Atlantico Vol. 10. Florence: Giunti
Pen and brown ink on paper
26.4 x 19.9 cm

Image:
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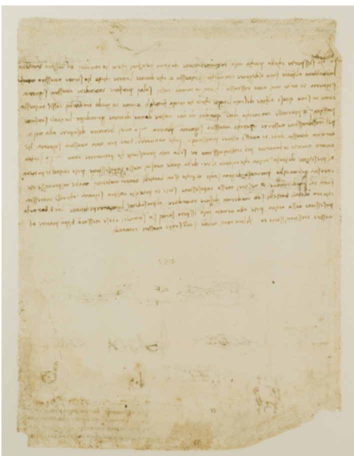

Two Draft Letters

Only a few letters by Leonardo have survived, among them the early "job application" to Ludovico Sforza (67 □) and the draft letters shown here about the implementation of Leonardo's royal privilege to take water from a Milan canal. The earlier collection fol. 1037v contains three letters on this matter addressed to various persons including Milan's governor, Charles d'Amboise (center). This delicate balancing act between respectfulness and pragmatic goals, which includes strategic references to the painting Leonardo had just completed for the French king, appears in fol. 872 r, reworked as a clean copy. The fact that Leonardo, who usually seemed so self-confident as an artist and scholar, made several drafts of a letter reveals his latent uncertainty about letter-writing. Leonardo tried to compensate for this by acquiring collections of model letters called *Epistolari* (43 □), written by authors with exemplary rhetorical skills.

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48. □ Leonardo da Vinci. ca. 1490. *Fables and facetious stories*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 207r

Reprint: 1973–1975. Il Codice Atlantico Vol. 3. Florence: Giunti

Pen and brown ink on paper

29.5 x 20.6 cm

Image:

05.02.03.01 - c

Leonardo had a penchant for fables and humorous literature. His library included not only numerous editions of Aesop (11 □] but also satirical works and bawdy stories known as *facetiae* (facetious stories) (44 □). He tried his own hand at writing in these two genres. His texts range from stylish well-crafted aphorisms to obscene droll stories—tailored to the tastes of different audiences. The sheet shown here contains moralizing fables about different types of trees amid scientific observations on plant growth. The trees in the fables include the citron, the peach, the nut tree, the fig, and the elm, each illustrated with little sketches and containing a moral message that the pursuit of as many and as large fruits as possible ultimately ruins the tree.

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World History and Natural History

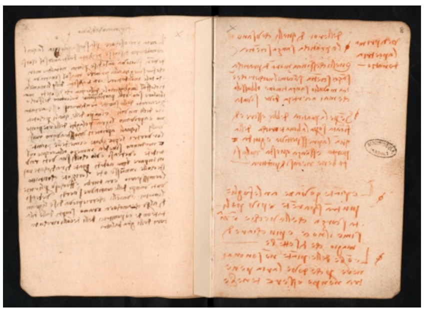
From the mountain that bears the name of the great bird, the famous bird will take flight, filling the world with its great glory.
Leonardo da Vinci
Codice sul volo degli uccelli, fol. 18v. Translation: Elizabeth Hughes

The canon of ancient works served artists (and scholars) such as Leonardo da Vinci and his contemporaries as inspiration for practical artistic design and for their own literary production. They drew on a wide variety of textual genres, from works of poetry, philosophy, and science to technical treatises. Authors from antiquity generally shaped the 15th-century view of nature and the human condition. Among the fundamental texts for the new understanding of nature was *Metamorphoses* by the Roman poet Ovid ((43 BCE–17 CE), one of the most important non-Christian sources in the history of art and literature, whose influence extended far beyond Leonardo's time. Ovid's concept of historical periodization into four world periods (based on Hesiod) proved to be particularly influential. His poetic narratives of the transformation of mythological figures into all kinds of plants, animals, and even constellations are interwoven with evocative portrayals of nature (and vivid descriptions). At the same time the *Metamorphoses* was an important compendium of ancient mythology.

The complex and multilayered didactic poem *De rerum natura* by the Roman philosopher Lucretius (ca. 99/94–ca. 55/53 BCE), was a significant rediscovery in the 15th century. Lucretius was a leading proponent of atomism, which was based on the natural philosophy of the Greek thinker Epicurus and his teachings on the atom. With its emphasis on the transience of being and the finite nature of the world, atomism represented the greatest conceivable contradiction to traditional Christian doctrine.

The worldview of Leonardo and his contemporaries combined the great historical narratives of the ancient and the Christian traditions. Natural history, world history, and the history of salvation combined to form a complex narrative that could also contain contradictions. This raised fundamental questions about the status of humans in nature, the essential character of time, and the relationship between transience and salvation.

Leonardo gradually collected the canonical works of ancient natural history in his library, and the ideas were echoed in his own drawings and writings. The processes of creation, transformation, and decay that Ovid and Lucretius described in their poetry also determined Leonardo's worldview and his understanding of human destiny. The focus for him was always on the forms of movement of living creatures and things, and—on both a large and small scale—on the transformation processes of nature.



Doomsday (116)

Leonardo’s Berlin Library: Section 6

49. □ Ovidius Naso, Publius. 1497. *Ovidio methamorphoseos vulgare*. Translated by Giovanni Bonsignori. Venice: Giovanni Rosso for Lucantonio Giunta
Sheets 10v–11r
Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kunstbibliothek. Shelfmark: 2° Gris 1063
Photo: Dietmar Katz

Image
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In the *Codex Atlanticus* (f. 195r) Leonardo cites Ovid’s *Metamorphoses* in the 14th-century Italian version by Arrigo de’ Simintendi da Prato. From this work, Leonardo borrowed the concept of “voracious” time as the “devourer of all things” and of nature, which is constantly being forced to change (116 □). The episode shown here tells the story of Phaeton, the son of the sun god Apollo (called Phoebus in the text), who, despite his father’s misgivings, is allowed to drive his sun chariot across the heavens for a day. But the son proves unfit for the task and unleashes a global conflagration, until Jupiter finally shoots the cocky lad and the chariot down from the sky with a thunderbolt.

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50. □ Lucretius Carus, Titus. 1500. *De rerum natura*. Edited by Hieronymus Avantius. Venice: Aldus Manutius
Sheets 6v–7r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 8° Inc 4510
Photo: Marvin Müller

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In 1417 the humanist Poggio Bracciolini rediscovered Lucretius' didactic poem *On the Nature of Things* in a monastery library in Germany. A first, albeit rare printed edition appeared in 1473, and was followed by others. This complex poetic work that denies the divine act of creation and propagates the transience of all things was discussed particularly in humanist circles in Florence as a challenge to the Christian view of history with its expectation of salvation. Leonardo, too, used Lucretius' thought as a basis for formulating his own worldview, defined by the transience of nature. Above all, he adopted its concept of atomism and translated the Lucretian concept of *semina rerum* (= seeds of things, meaning atoms) as "semenze" (*Codex Atlanticus*, fol. 207 v). On this page of the first book shown here, Lucretius is extolling the *Venus Genetrix* as the giver of all life.

REFERENCES

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51. □ Livius, Titus. 1493. *Deche di Tito Livio vulgare historiate*. Venice: Giovanni Rosso for Lucantonio Giunta
Title page
Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kupferstichkabinett. Shelfmark: 2° 2517
Photo: Dietmar Katz

Image:
06.01.01.03

Leonardo's book lists note this historical work by Titus Livius as an edition in three separate volumes corresponding to the three surviving decades (compositions of the original individual books in groups of ten) (3 □; 4 □). The note probably refers to the richly illustrated Venetian edition in an Italian translation. The depictions of battles, such as those on the title page of the first decade (that is, in the first volume) were particularly important for Leonardo.

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52. □ Plinius Secundus, Gaius. 1481. *Historia naturale*. Translated by Christophorus Landinus. Venice: Filippo di Pietro
Sheets 12v–13r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3732
Photo: Marvin Müller

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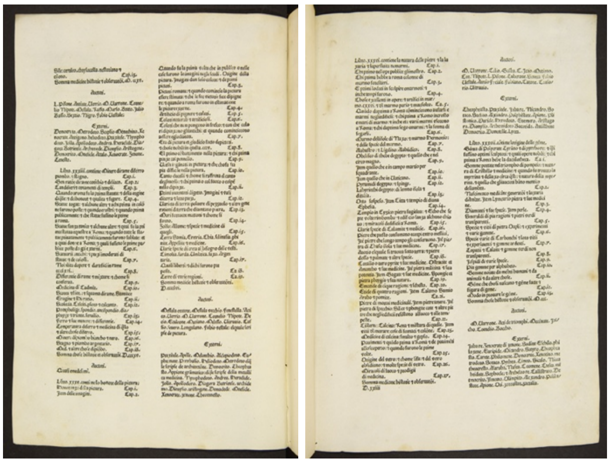

Pliny's *Natural History* is one of the key works in Leonardo's library. It gave him access to a wide range of fields in the natural sciences (cosmology, geology, zoology, botany, mineralogy, metallurgy, etc.). Aside from this, Pliny's text is one of the most important sources of art history in antiquity and on artistic techniques, which he discusses in relation to the science of materials (books XXXIII–XXXVII; the contents list is shown here). The text in the Italian translation by the humanist Cristoforo Landino also served Leonardo as a model for his own sketchy literary attempts, which are known by the titles *The Sea Monster and the Cave* (*Codex Arundel*, fol. 155r–156v); and *A Bestiary* (*Codex H*, fol. 19r–27v).

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Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 85, sec. 2.2.

53. □ Foresti, Giacomo Filippo. 1486. *Supplementum chronicarum*. Venice: Bernardinus Benalius
Sheet a1r
Staatliche Museen zu Berlin – Preußischer Kulturbesitz, Kunstbibliothek. Shelfmark: 2° Gris 1273
Photo: Dietmar Katz

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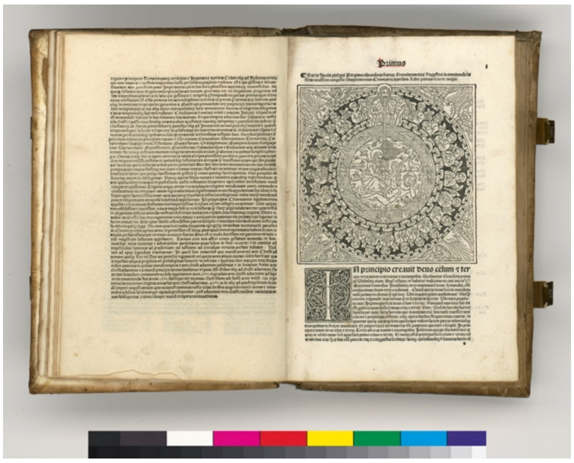

The *Supplementum Chronicarum* by the Augustine monk Giacomo Filippo Foresti (1434–1520), who originated from Bergamo, is a compilation of the history of the world drawn from different sources and traditions. The book is richly illustrated. The page shown here, with the vision of the divine Creation, is particularly impressive. The accompanying text is based on the biblical history of Genesis but at this point does not explicitly mention the creation of human beings on the sixth day. The illustration, however, follows the established Christian tradition for depicting this scene and focuses on the creation of Eve. Aside from biblical scenes, the work primarily contains a large array of "portraits" of famous cities like Rome and Venice. In 1495 Leonardo bought a *"Cronica"* (*Codex Atlanticus*, f. 288r) in Milan for 68 soldi; this could refer to one of two works, either Foresti's *Supplementum Chronicarum* or the *Schedelsche Weltchronik* (54 □).

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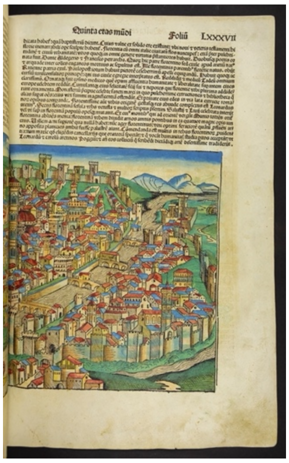
54. □ Schedel, Hartmann. 1493. *Liber chronicarum*. Nuremberg: Anton Koberger
Sheets LXXXVIv–LXXXVIIr
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Inc 1743e
Photo: Marvin Müller

Images:
[06.01.01.06 - L]
[06.01.01.06 - R]

The *Schedelsche Weltchronik* (Schedel's World History) is named after its author, the physician and humanist Hartmann Schedel (1440–1514) from Nuremberg. Containing over 1,800 woodcut illustrations by Dürer's teacher, Michael Wolgemut, it is one of the most opulent book projects of the early modern period. Written in the tradition of medieval universal chronicles, which were heavily influenced by biblical salvation history, it presents the historical knowledge of its time divided into six epochs, from the Creation to the year 1493. The inclusion of geographical representations, like that shown here of the authentic, up-to-date view of the city of Florence with Brunelleschi's cathedral dome (29 □; 30 □) and the church façade of Santa Maria Novella by Alberti, is particularly characteristic. Schedel could refer to his extensive private library—the biggest of its time in Germany—and his enormous collection of graphic works.

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Posselt, Bernd. 2015. *Konzeption und Kompilation der "Schedelschen Weltchronik*." Vol. 71. Monumenta Germaniae historica: Schriften. Wiesbaden: Harrassowitz.

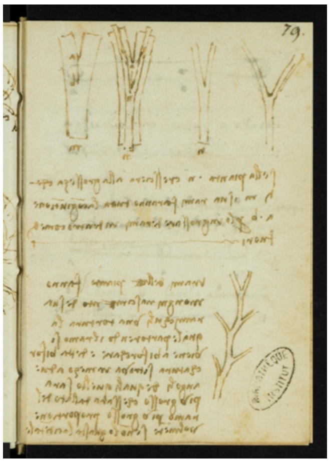
Wagner, Bettina, ed. 2014. *Welten des Wissens. Die Bibliothek und die Weltchronik des Nürnberger Arztes Hartmann Schedel (1440–1514).* Exhibition catalogue Bayerische Staatsbibliothek Munich, 19.11.2014–1.3.2015. Munich: Allitera.

Natural Forms

55. □ Leonardo da Vinci. 1495–1500. *Studies of tree growth*. *Paris MS M*. Institut de France, Paris, fol. 78v–79r

Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS M. Florence: Giunti
Pen and brown ink on paper
10 x 7 cm + 10 x 7 cm

Images:
06.02.02.01 - L
06.02.02.01 - R



Preparatory drawings and studies of plants were indispensable for Leonardo's paintings, such as his early picture *The Annunciation* (17 □) with the significant symbolism of its carpet of spring flowers. But before long, his pure subject studies of external appearance aimed at faultless identification of individual species transcended their main artistic objective and evolved into a systematic observation of the internal organic structure. Leonardo's botanical studies tried to grasp the function of the plant organism and express it graphically. He was primarily interested in processes of transformation and growth, and their regularity.

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Heydenreich, Ludwig H. 1943. *Leonardo*. Berlin: Rembrandt-Verlag, 199–200.

56. □ *Preserved tree (bonsai)*
Museum für Naturkunde, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Preserved specimen
72 x 90 x 65 cm (h x w x d)

Image:
06.02.03.02

Analytical observations of nature play a major role in Leonardo's scientific work and also permeate his artistic creations. In his studies of tree growth, he attempted to discover the laws of organic growth processes (55 □). The Japanese bonsai is a living plant organism whose growth is stunted by human intervention. The tree's miniature format means that the whole structure above and below the soil can be presented in a conserved form in the exhibition. This Far Eastern art of gardening, which originated in Han dynasty China (206 BCE–220 CE), symbolizes the effort not just to satisfy the human desire for aesthetic design by imitating nature but also to achieve the perfect form—a familiar theoretical principle for Italian Renaissance artists.

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57. □ Leonardo da Vinci. ca. 1512–1513. *The bones and muscles of a bird's wing*
Royal Library, Windsor. Inv.: RCIN 912656

Pen and brown ink, black chalk, on paper
22.2 x 20.4 cm
Reproduction

Image:
06.02.02.04

This sheet combines four studies on the anatomy of a bird's wing with written explanations, clearly recalling Leonardo's famous anatomical studies of human limbs (69 □). Aside from the structural composition, Leonardo was also interested in how the wing functioned and the sequence of movements. On the right edge of the sheet is a tiny sketch of a small bird in flight, similar to the sketches in his treatise on avian flight. Leonardo began his attempts at flying by experimenting with an *ornithopter*. Based on the physical structure of a bird, its pinions were designed to be moved by human muscle power. After this idea failed, Leonardo intensified his observations of birds gliding, particularly the kite.

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Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 248–249.

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58. □ *Skeleton of a blackbird*
Museum für Naturkunde, Berlin. Inv.: 2000/15240
Photo: Yvonne Rischke, Kiwi-Foto
Preserved specimen
16 x 13 x 25 cm (w x d x h)

Image:
06.02.03.01

The blackbird (*Turdus merula*, Italian: *merlo*) belongs to the thrush family and is one of the most widespread songbirds in Europe. Today, it is also indigenous to cities as a synanthropic bird. In Leonardo's times, it was still a forest bird. The blackbird is mainly known for its melodious territorial song. Although blackbirds spend most of their time hopping around searching for food on the ground, they are extremely agile in flight. On landing they brake their momentum with a series of steps, typically raising their tails. Leonardo observed the importance of the tail for bird flight in nature and analyzed the skeleton of the birds in painstakingly detailed anatomical studies (57 □). He tried to incorporate both these observations into the construction of his own flying apparatus, the great bird ("*grande uccello*") (114 □). The blackbird appears as the adversary of the privet in one of his fables (*Codex Atlanticus*, fol. 187r).

REFERENCES

Glutz von Blotzheim, Urs Noel, ed. 1988. *Handbuch der Vögel Mitteleuropas. Passeriformes. 2. Teil - Turdidae - Echte Drosseln*. Vol. 11.2. 14 vols. Wiesbaden: Aula.

Early and Late Times

59. □ Leonardo da Vinci. 1497–1499. *Fossils*. *Paris MS I*. Institut de France, Paris, fol. 25r
Reprint: Marinoni. 1987. I Manoscritti dell'Institut de France: MS I. Florence: Giunti
Pen and brown ink on paper
10 x 7.5 cm

Image:
06.02.02.02

Surrounded by little decorative shapes, this sheet includes structures resembling marine fossils. Leonardo was particularly interested in the phenomenon of shell deposits in mountains and places far from the sea, such as those found in many geological formations in northern Italy. He vehemently rejected the explanation of his time that these were residues from the age of the biblical Deluge. In the *Codex Leicester,* he responded that a mussel was able to move a maximum distance of 3–4 ells per day and could not possibly have covered the 250 miles between the Mediterranean and the mountains of Lombardy in the 40 days the Deluge lasted. He concluded that the sea had originally reached to the heights of the Italian mountain ranges.

REFERENCES

Cioppi, Elisabetta, and Stefano Dominici. 2018. "Fossils and Landscape Forms in Leonardo's Living Tuscany." In *Water as Microscope of Nature. Leonardo da Vinci's Codex Leicester.* Exhibition catalogue Galleria degli Uffizi, Florence, 30.10.2018–20.1.2019, edited by Paolo Galluzzi. Florence: Giunti, 170–183, ibid. Cat. 18, 381 (Agnese Sabato).

Heydenreich, Ludwig H. 1943. *Leonardo*. Berlin: Rembrandt-Verlag, 263–265.

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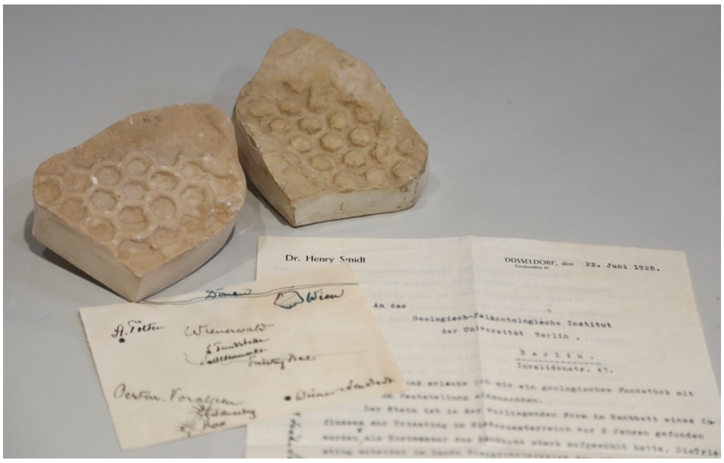
60. □ *Fossils (Paleodictyon isp.)*
Museum für Naturkunde, Berlin, Inv.: MB.W.791a.-b
Photo: Yvonne Rischke, Kiwi-Foto
Plaster cast
15 x 15 cm

Image:
[06.02.03.03]



The *paleodictyon* is a trace fossil whose tunnel-like passages survived the ages in high relief form and are interpreted as the dwelling of a worm-like sea creature. Deposits have been documented in Early Cambrian sediments. The characteristically hexagonal, honeycomb-like structures are found especially in the pre-Apennine valley and were first described by Giuseppe Meneghini (1811–1889), a paleontologist working in Tuscany. But Leonardo was probably aware of similar finds, as revealed by the honeycomb structure he drew on a sheet in the *Paris MS I* (59 □). The specimen here was found in 1926 in the stream bed (Flysch sedimentary rock) of a tributary of the Triesting near Altenmarkt in Lower Austria (Vienna Woods).

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Baucon, Andrea. 2010. “Leonardo da Vinci. The Founding Father of Ichnology.” *Palaios* 25 (5/6): 361–367.

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61. □ Leonardo da Vinci. ca. 1513–1518. *The Deluge*
Royal Library, Windsor. Inv.: RCIN 912376

Black chalk, pen and ink, wash on paper

27 x 40.8 cm
Reproduction

Image:
06.02.02.03

Unlike traditional artistic representations of the Deluge, Leonardo's series of drawings on this topic do not focus on the narrative, let alone the fate of particular creatures. Instead, they concern the visualization of analogous phenomena related to the spiraling of air, smoke, and water, on the impact of force, and the movement of matter in general. Leonardo observed these phenomena in his studies on the behavior of water currents and repeatedly made drawings of them (96 □). The wind gods depicted here hiding between dense clouds could be seen as a last reminder of classical texts like Ovid's *Metamorphoses*. The horsemen at the bottom right of the sheet are barely recognizable. Their desperate struggle recalls Leonardo's painting *The Battle of Anghiari* and demonstrates the uncontrollable violence of the elements.

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Challenges of Technology

Mechanics is the paradise of mathematical sciences, because through it one reaches the fruit of mathematics.
Leonardo da Vinci
Paris MS E, fol. 8v. Translation: Elizabeth Hughes

Leonardo was able to develop his technical understanding and knowledge from an early age as a pupil in the workshop of the versatile painter, sculptor, and goldsmith Andrea del Verrocchio, an expert in various artistic techniques and materials. Leonardo admired the machines that Filippo Brunelleschi had developed for the construction of the dome of the Florence Cathedral. (The copper sphere of the dome lantern that Leonardo later referred to in his writings was made in the Verrocchio workshop.) When Leonardo moved to Milan in 1482, where he had successfully applied for a permanent position at the Sforza court, primarily as a military engineer, he deepened his technical knowledge in many areas. An ambitious autodidact, he studied contemporary specialist technical literature and became a prototype of the artist-engineer. Two predecessors who particularly impressed him were Mariano di Jacopo Taccola (1382–1458) and Francesco di Giorgio Martini (1439–1501), both from Siena. The latter, like Leonardo, was a versatile artist-engineer in court service. Leonardo's technical interests were fundamentally influenced by the extensive writings of Roberto Valturio (1405–1475), which belonged to his library. Leonardo's wide-ranging interests, his love of experimentation, and his power of imagination, but not least his outstanding skills as a draftsman, soon enabled him to surpass his role models and opened up previously unknown possibilities in the visualization of technical relationships.

Span of a bridge (113 □)

Leonardo’s Berlin Library: Section 7

62. □ Kyeser, Konrad. ca. 1430. *Bellifortis*. Bayerische Staatsbibliothek Munich: Clm 30150
Reprint: Ulrich Montag, ed. 1967. Berlin: Kulturstiftung der Länder
Fol. 38v and 42r (Plates 9–10)
Max Planck Institute for the History of Science, Berlin. Shelfmark: 623.09 K825

Image:
07.01.01.05

The *Bellifortis* (War fortifications) is the first complete illustrated manual of military technology and the earliest technical encyclopedia in the German-speaking world. Its author, the physician and jurist Konrad Kyeser (1366–after 1405) from Eichstätt acquired all kinds of practical knowledge of war technology in the service of the kings Sigismund of Hungary and Wenzel of Bohemia. Intended for a courtly audience, the work was created in 1402 after Kyeser had fallen from grace politically. The manual was partly a bid to re-enter courtly service again. It presents war equipment and machines for a wide variety of purposes as well as inventions for civilian use. Although the work was never printed, numerous handwritten copies in various versions circulated all over Europe, and its drawings—some of which seem quite fantastical—inspired many treatises on the art of engineering and machine construction. The accompanying texts in Latin hexameters, however, are often incomprehensible. The illustrations here show a windmill-powered lift and an original method of crossing rivers with horses.

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Cermann, Regina. 2013. *Der “Bellifortis” des Konrad Kyeser*. Codices manuscripti & impressi, Supplementum 8. Puskersdorf: Verlag Bruder Hollinek.

Leng, Rainer. 2009. “Feuerwerks- und Kriegsbücher. Konrad Kyeser, ‘Bellifortis’ (einschließlich Hartlieb und ‘Bellifortis’-Bearbeitungen). Nr. 39.4.” In *Katalog der deutschsprachigen illustrierten Handschriften des Mittelalters, hg. von der Kommission für Deutsche Literatur des Mittelalters der Bayerischen Akademie der Wissenschaften, begonnen von Hella Frühmorgen-Voss. Fortgeführt von Norbert H. Ott zusammen mit Ulrike Bodemann und Gisela Fischer-Heetfeld*. Munich: C.H. Beck, 4, part 2, lot 3–4:145–512.

63. □ Valturius, Robertus. 1483. *De re militari*. Verona: Boninus de Boninis

Sheets u5v–u6r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 4575
Photo: Marvin Müller

Images:
07.01.01.01 - L
07.01.01.01 - R

De re militari by the humanist Roberto Valturio (1405–1475) from Rimini is a treatise on the art of war mostly based on the writings of authors from antiquity. The many woodcut illustrations of weapons and war machines inspired Leonardo to make his own, far more precise engineering drawings (113 □). He also used the text to compile vocabulary lists in the *Codex Trivulzianus* (108 □). The double page here shows an Arab siege machine, apparently made of basketwork and in the form of a fearsome dragon, loading a complement of men as well as military equipment like bridges, ladders, and artillery. On the right-hand side are two devices for draining water from moats.

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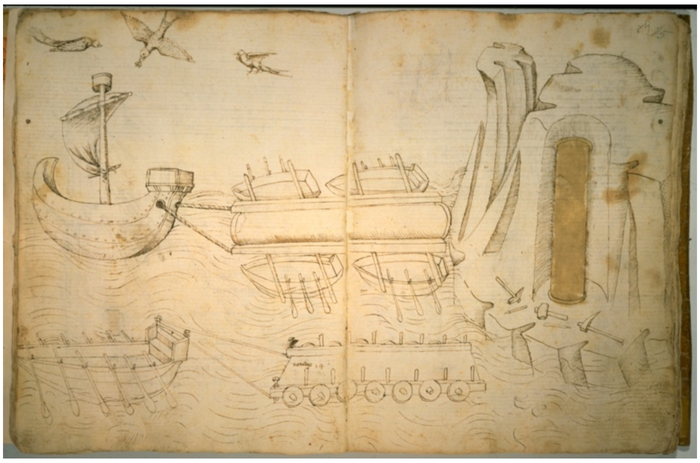
Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 93, sec. 6.1, 6.2.

64. □ Taccola (Mariano di Jacopo). 1432–1433. *De ingeneis III–IV*. Biblioteca Nazionale Centrale di Firenze: Palatino 766
Fol. 14v–15r
Facsimile
Museo Galileo, Florence

Image
07.01.01.02



The Sienese engineer Mariano di Jacopo, known as Taccola (1382–1458), was one of the leading representatives of the mechanical arts of the early 15th century. Books III and IV of his surviving manuscript work *De ingeneis* (written between 1431 and 1433) are mainly devoted to constructional engineering and hydraulic engineering. This book of drawings circulated in numerous Renaissance workshops and influenced many of Leonardo's technical projects. Sheets 14v–15r show the transport of a column drum from a quarry over land and by water.

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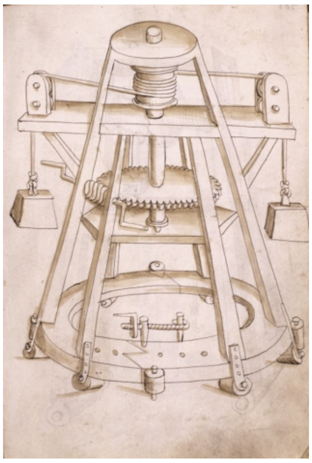
Galluzzi, Paolo. 1991. *Prima di Leonardo. Cultura delle macchine a Siena nel Rinascimento.* Exhibition catalogue Magazzini del Sale, Siena, 9.6.–30.9.1991. Milan: Electa.

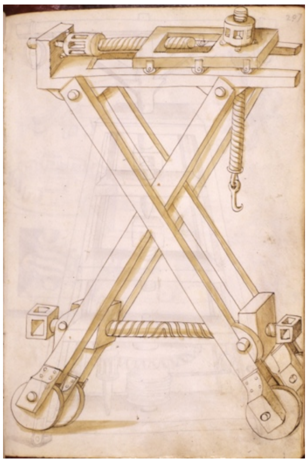
Prager, Frank D., and Gustina Scaglia. 1972. *Mariano Taccola and His Book "De ingeneis."* Cambridge, Mass.: MIT Press.

Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 91, sec. 5.1.

65. □ Taccola (Mariano di Jacopo) and Francesco di Giorgio Martini. ca. 1480. *Disegni di macchine*. Biblioteca Nazionale Centrale di Firenze: Palatino 767
Fol. 206–207
Facsimile
Museo Galileo, Florence

Images
07.01.01.03 - L
07.01.01.03 - R





This double page is part of a 268-page parchment codex with a collection of drawings based on the manuscripts of Taccola (*De ingeneis*) and those of Francesco di Giorgio Martini. Drawn by a confident hand, they were probably made by an artist from Francesco di Giorgio's workshop, perhaps Guidoccio Cozzarelli. Such model machine drawings were widespread in Renaissance workshops. Shown here is a two-armed hoist powered by a crank and a cog wheel, and on the right, an adjustable mobile hoist.

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Scaglia, Gustina. 1992. *Francesco Di Giorgio. Checklist and History of Manuscripts and Drawings in Autographs and Copies from ca. 1470 to 1687 and Renewed Copies (1764–1839)*. Bethlehem: Lehigh University Press, 70–73.

Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 91, sec. 5.2.

66. □ Martini, Francesco di Giorgio. 1478–1481. *Trattato di architettura e macchine*. Biblioteca Medicea Laurenziana di Firenze: *MS Ashburnham 361*

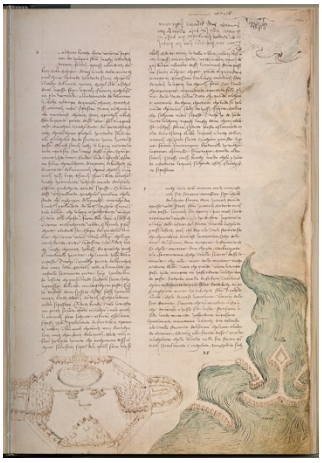
Fol. 24v–25r

Facsimile

Museo Galileo, Florence

Image

07.01.01.04



The *Trattato di architettura e macchine* (Treatise on architecture and machines) is the most important theoretical work by the Sienese engineer, architect, sculptor, and painter Francesco di Giorgio Martini (1439–1501), whom Leonardo knew personally. This first version, an elegant parchment manuscript with text in two columns and drawings, was made around 1478–1481 in Urbino. To date, this is the only book that seems to have been identified as having been owned by Leonardo da Vinci. Twelve marginal notes (*marginalia*) apparently written by him reveal his careful study of the text in the years around 1504. At that time, Leonardo also used a second, later version of this work, from which he copied individual passages (*Codex Madrid II*, ca.1503–1504).

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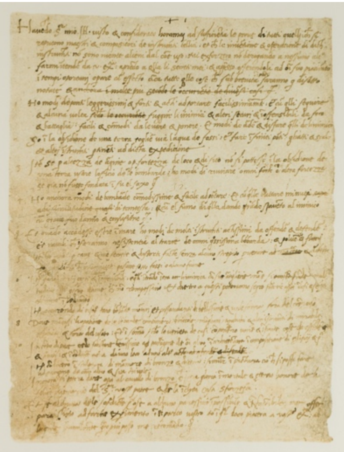
Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 112, sec. 10.1.

The Technology Argument

67. □ Leonardo da Vinci. ca. 1482. *"Job application" to Ludovico Sforza*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1082r
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Pen and brown ink on paper
25 x 19 cm

Image:
07.02.02.02



A few years after his arrival in Milan, Leonardo tried to obtain a post at the Duke of Sforza's court by recommending himself to Ludovico il Moro as a military engineer. He did not compose the draft letter shown here alone—it was written with the help of a friend or colleague. The many Latinisms in the text are unusual for Leonardo's writing style. The application concentrated first of all on Leonardo's military expertise (including plans for light, transportable temporary bridges, fortifications, artillery pieces, etc.). Only at the very end does he mention his artistic skills—first as a sculptor and bronze caster (with a view to the equestrian monument Sforza was planning (68 □)) and, last of all, as a painter.

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Marani, Pietro C., ed. 2019. *Lettres de Léonard de Vinci. Aux princes et aux puissants de son temps*. Rome: De Luca Editori d'Arte.

Vecce, Carlo, ed. 2019. *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019. Florence: Giunti, 94, sec. 6.3.

68. □ Leonardo da Vinci. 1491. *Model for the cast of the Sforza horse*. *Codex Madrid II*. Biblioteca Nacional de España, Madrid, MS 8936, fol. 157r
Reprint: Reti. 1974. I Codici di Madrid II. Florence: Giunti-Barbèra
Red chalk on paper
21 x 14.6 cm

Image:
07.02.02.03

Leonard spent more than 16 years creating the bronze equestrian monument to Francesco Sforza. Aside from the ambitious artistic design, he concentrated most of his efforts on the technical implementation of the elaborate casting process, which was not without risk. It involved the construction of smelters and a conduit system for 70 metric tons of liquid metal, as well as machines to haul up the nine-meter-high casting mold that had been partly buried in the ground. The drawing shows the outer coat (*cappa*) around the central cast core with the specially developed corset-like metal bindings. The technical similarity of this process to cannon casting eventually proved disastrous for the project: after the French invasion the bronze was used for artillery production, while French archers used Leonardo's colossal clay model of the horse as a shooting target.

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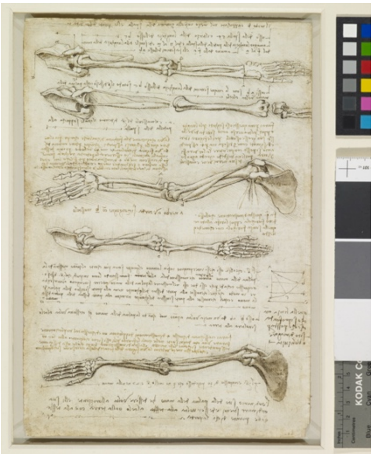
Body Mechanics

69. □ Leonardo da Vinci. 1510–1511. *The bones and muscles of the arm*. *Corpus of the Anatomical Studies*, fol. 135v
Royal Library, Windsor. Inv.: RCIN 919000v
Royal Collection Trust © Her Majesty Queen Elizabeth II 2021
Black chalk, pen and brown ink, wash on paper
29 x 20 cm
Reproduction

Image:
07.02.02.01



In Padua in the winter of 1510–1511 Leonardo performed a large number of anatomical sections to investigate mechanisms of the human body, probably under the guidance of the anatomy professor Marcantonio della Torre. He recorded his observations in visually mature and extremely didactic drawings, which were probably intended for publication from the outset. This sheet examines step by step the rotation of the human arm with the palm turning upward (*supination*) and downward (*pronation*). The upper drawing shows the top view of the shoulder and arm, first with the bones in their normal position and then, to make things clearer, separately from each other. The third drawing is a frontal view extended by the two cords of the *biceps brachii*. Below this are two representations of *pronation* viewed from above and from the back.

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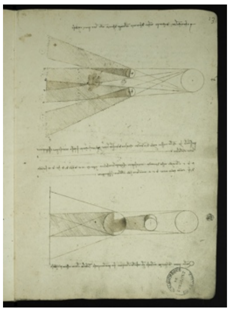
Science as Art, Art as Science

The painter who depicts something only through practice and judgment of the eye without reason is like a mirror that imitates all things placed in front of it without recognizing them
Leonardo da Vinci
Codex Atlanticus, fol. 207r. Translation: Elizabeth Hughes

The many and varied technical tasks Leonardo had to master in the service of the Sforzas were closely linked to scientific problems and challenges. But also the practice of the visual arts, especially painting, increasingly required theoretical knowledge and diverse expertise, particularly in the cultivated context of the court. This ranged from questions of optics and mathematical perspective construction to mechanical problems and medical knowledge. Leonardo now tried to learn systematically from the existing fundamental works by ancient authors related to all these disciplines, as well as from medieval sources and a growing number of more recent treatises. He expanded his library with specialist scientific literature and made concentrated and ambitious efforts to learn Latin and deepen his mathematical knowledge. This eventually enabled him to formulate new scientific insights of his own. He had now become an “author” of scientific works in his own right. Other artist-engineers, from Leon Battista Alberti (1404–1472) and Piero della Francesca (ca. 1420–1492) to Albrecht Dürer (1471–1528), also sought to place painting, which at the time was still considered a purely practical craft, on a scientific footing. Leonardo went one step further and elevated painting itself to a science.

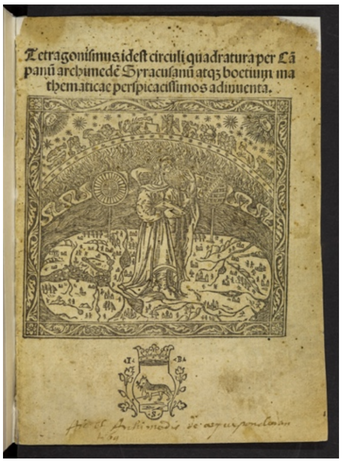


Cast shadows (110 □)

Leonardo’s Berlin Library: Section 8

70. □ Archimedes, Johannes Campanus, and Severinus Boethius. 1503. *Tetragonismus*. Edited by Luca Gaurico. Venice: Giovanni Battista Sessa
Title page
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° 37 MA 12201
Photo: Marvin Müller

Image:
[08.01.01.02]



The anthology edited by the humanist Luca Gaurico (1475–1558) on the problem of the quadrature of the circle marked the first-ever printing of works by Archimedes (ca. 287–212 BCE): *De quadratura parabolae* (*The quadrature of parabolas*) and *De mensura circuli* (The measurement of circles). One of Leonardo’s book lists (4 □) records a “Quadrature of the Circle” that can be identified as the edition by Gaurico. Leonardo studied Archimedes intensively during the years around 1504. Pomponio Gaurico, Luca’s brother, mentioned in his text *De sculptura* that Leonardo was famed for being as great a genius as Archimedes. The title page shows Archimedes as a giant in the middle of the Earth with his head towering above in the sublunar sphere of the element of fire.

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71. □ Euclid, Jordanus Nemorarius, Gerardus de Brussel, Archimedes, Johannes de Tinemue, Theodosius, Geber, and Alfraganus *et al*. 13th c. *Miscellanea*
Fol. 102v–103r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: MS lat. qu. 510
Photo: Marvin Müller

Images:
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The 13 books of the *Elements* (Greek: *Stoicheia*) by Euclid (ca. 300 BCE) summarize the mathematical knowledge of the time in a systematic and exemplary way, dealing with surface and spatial geometry, arithmetic, number theory, and proportion theory. It was used as a textbook for over 2,000 years in countless copies, editions, and translations. This makes the *Elements* one of the most influential and durable works not only in science but also in world literature as a whole. In Europe in the Middle Ages, the *Elements* was used first of all in Latin translations from the Arabic, such as the manuscript shown here based on the 12th-century version by the Englishman Adelard of Bath. The text was printed for the first time in Venice in 1482 in a version from 1255 edited by Johannes Campanus (12 □), and was used by Leonardo.

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Steck, Max. 1981. *Bibliographia Euclideana. Die Geisteslinien der Traditionen in den Editionen der "Elemente" (ΣΤΟΙΧΕΙΑ) des Euklid (um 365–300). Handschriften – Inkunabeln – Frühdrucke (16. Jahrhundert). Textkritische Editionen des 17. Jahrhunderts. Editionen der "Opera minora" (16.–20. Jahrhunderts)*. Arbor scientiarum. C. 1. Hildesheim: Gerstenberg.

72. □ Peckham, Johannes. 1482. *Prospectiva communis*. Edited by Facius Cardanus. Milan: Petrus de Corneno
Sheets a1v–a2r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3247.5
Photo: Marvin Müller

Images:
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08.01.01.01 - R

The *Prospectiva communis*, completed in 1279 by the English Franciscan John Peckham (ca. 1230–1292), is one of the most comprehensive medieval treatises on optics. Leonardo used it as a basis for his own optical experiments (110 □). Its sources include the Arab tradition of Alhazen which, in turn, builds on the ancient optics of Euclid and Ptolemy (9 □). The work was edited in Milan in 1482 by the mathematician Fazio Cardano, who was a personal friend of Leonardo's. He helped him in the search for rare books and perhaps also with translations from Latin. A glossary among Leonardo's papers compiled from Peckham's work, but not in Leonardo's handwriting, could have been written by Cardano. Elsewhere, Leonardo himself copied down an Italian translation of the introduction to Peckham's work.

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73. □ Archimedes and Piero della Francesca. 1468–1492. *Opere*. Biblioteca Riccardiana di Firenze: Ricc. 106
Fol. 22v–23r
Facsimile
Museo Galileo, Florence

Images
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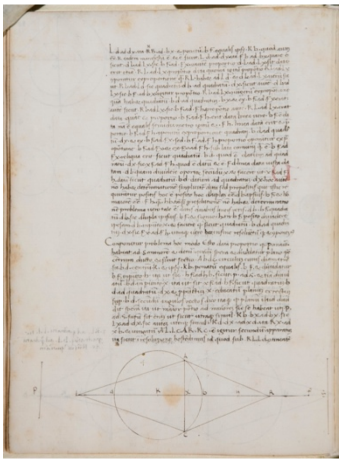
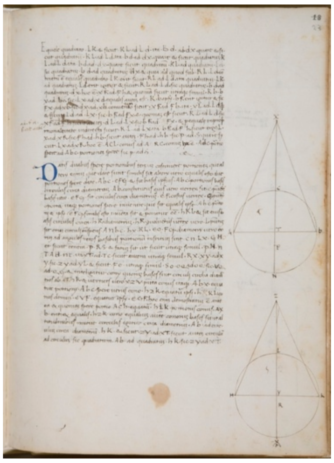
08.01.01.03 - R





Archimedes' works were translated into Latin for the first time in 1269 by Wilhelm von Moerbeke, and again in 1450 by Iacopo of Cremona (or San Cassiano). They are important for mechanics and engineering as well as for the mathematical foundations of perspective and painting. This specimen from the Biblioteca Riccardiana is a handmade copy by the painter Piero della Francesca based on the Latin by San Cassiano with carefully crafted illustrations. Leonardo made several searches on different occasions for the works of Archimedes. In particular, in 1502 he mentioned a codex from "Borgo a San Sepolcro," probably referring to the manuscript by Piero della Francesca, who came from that town.

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74. □ Pacioli, Luca. 1494. *Summa de arithmetica, geometria, proportioni et proportionalita*. Venice: Paganinus de Paganinis
Sheets 81v–82r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 4269
Photo: Marvin Müller

Images:
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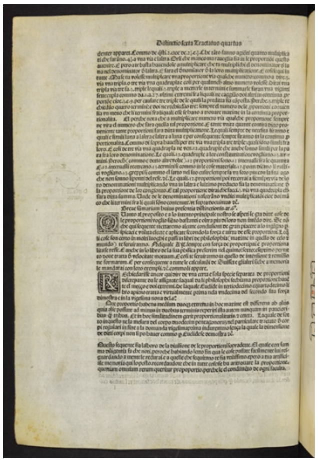

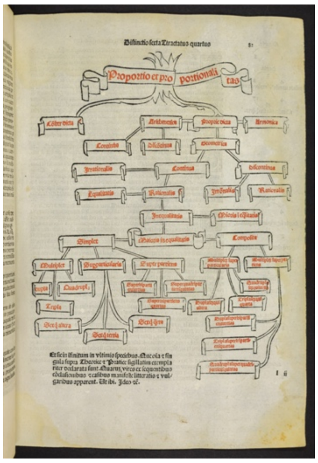

The *Summa* by the Franciscan Luca Pacioli (ca. 1445–1517) belongs to the tradition of treatises on the abacus. It consists of two parts covering arithmetic, algebra, bookkeeping, and geometry. Leonardo bought the book in 1495 for 119 soldi (*Codex Atlanticus*, fol. 288r) to improve his skills in mathematics and geometry. He transferred numerous excerpts from it into his codices (for example, the memory diagram for the tree of proportions and of proportionality). Shortly afterwards he met Pacioli in person and worked closely with him. Thanks to this meeting Leonardo was able to expand his mathematical knowledge considerably, while Pacioli benefited, among other things, from his friend's analytical drawing skills (86 □).

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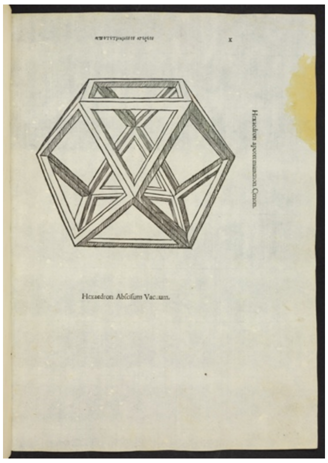
75. □ Pacioli, Luca. 1509. *Divina proportione: Opera a tutti glingegni perspicaci e curiosi necessaria*. Venice: Paganini de Paganinis
Plate X
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Nu 7780a
Photo: Marvin Müller

Image:
08.01.01.06



In 1498 Pacioli wrote a major work titled *Divina proportione* (On the divine proportion). Two magnificent manuscripts of this work exist with dedications to important personages. The treatise was printed in Venice in 1509 in an expanded form with two new sections, on architecture and regular polyhedra. In the manuscripts (86 □) and the printed edition, the splendid plates with illustrations of polyhedra were based on drawings by Leonardo. They are the only works of his that were printed in his lifetime. In the foreword, Pacioli explicitly paid tribute to his friend Leonardo, the artist-engineer.

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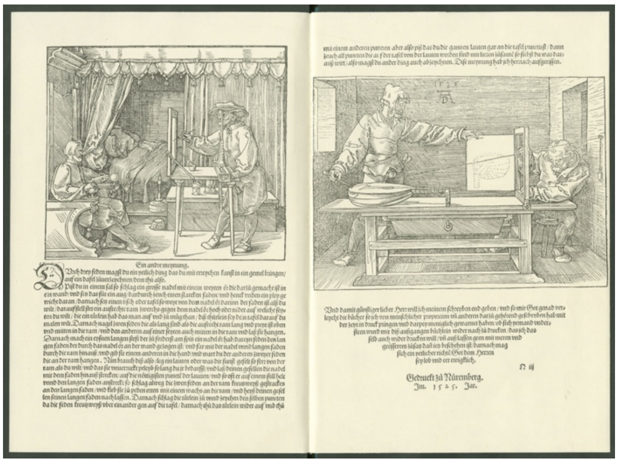
76. □ Dürer, Albrecht. 1525. *Underweysung der Messung, mit dem Zirckel und Richtscheyt, in Linien, Ebenen unnd gantzen corporen*. Nuremberg: Hieronymus Andreae
Reprint: 1983. Nördlingen: Uhl
Sheets q2v–q3r
Max Planck Institute for the History of Science, Berlin. Shelfmark: Sou 2 D853u

Image:
08.01.01.08



The painter Albrecht Dürer from Nuremberg wrote this textbook on descriptive geometry as an introduction for young artists. His goal was to provide painting in his home country with the mathematical basis it already had in Italy. During his stay in Venice, he bought the latest Latin edition of Euclid’s *Elements* (Venice: Giovanni Taccuino, 1505) for the price of one ducat, as he noted on the title page. He also planned to get an introduction to the art of “secret perspectives” in Bologna, possibly, like Leonardo, from Luca Pacioli (and perhaps at the suggestion of the Venetian Jacopo de’ Barbari (78 □), who worked in Nuremberg for a time). The woodcuts illustrate two detailed descriptions of the right methods of depicting foreshortening of perspective.

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77. □ Ketham, Johannes de. 1500. *Fasciculus medicinae. Similitudo complexionum & elementorum*. Venice: Johannes and Gregorius de Gregoriis
Sheets c2v–c3r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3898
Photo: Marvin Müller

Images:
08.01.01.07 - L
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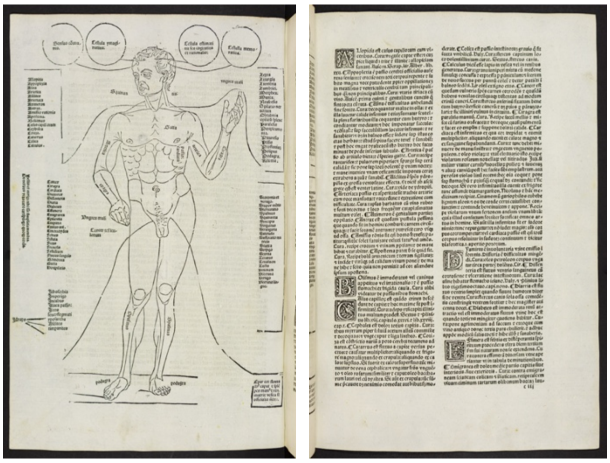

First published in Latin in 1491, the *Fasciculo de medicina* (CR to Nova) was translated into Italian by Sebastiano Manilio and reprinted in 1494 in an expanded edition with an Italian version of Mondino's *Anatomy* and numerous large-format illustrations. These pictures related first to the practical work of the physician and surgeon (teaching, anatomical dissection, patient visits), and second to representations of the inner organs of the human body. Leonardo probably used both the Latin and the Italian edition. He used the woodcut illustrations as a starting point but immediately surpassed them with his own incomparably more precise anatomical drawings, setting new standards in the analytical depiction of physiological connections (87 □; 69 □). Leonardo's goal was to produce his own anatomical treatise.

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Geometric Art

78. □ Jacopo de' Barbari. ca. 1495–1500. *Portrait of Fra' Luca Pacioli and Disciple*
Museo e Gallerie Nazionali di Capodimonte, Naples. Inv.: Q 58
akg-images
Oil on wood
99 x 120 cm
Reproduction

Image:
08.02.02.03

With the cowl of his monk's habit resembling a triangle, this double portrait by Jacopo de' Barbari (ca. 1475–1516) shows the Franciscan friar and mathematician Fra' Pacioli as an authoritative geometry teacher. He was evidently associated with other illustrious pupils besides Leonardo—although the identity of the elegant young man in the lynx fur has never been definitively confirmed. The name inscribed in the frame of the slate is Euclid, whose *Elements* the master is using to demonstrate a theorem printed in the edition by Ratdolt (12 □). Further to the right in the picture, in a costly red binding and identifiable from the spine, is de' Barbari's own recently published textbook, *Summa de arithmetica* (74 □). The wooden dodecahedron and the transparent polyhedron—probably conceived as imaginary—refer to one of Pacioli's areas of research, to which Leonardo's art would shortly give shape (75 □; 86 □).

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79. □ *Compass*, 20th c.
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Wood, brass, graphite
16 x 3.5 x 3 cm (l x w x d)

Image:
08.02.03.04

The compass, together with the ruler, was the most important instrument for mathematicians ever since antiquity. Classical tasks of geometry such as the Delian problem (doubling of a cube volume) (35 □) could only be solved with the aid of these tools. This is shown by the subtitle *Mit dem Zirckel und Richtscheydt* (*With the compasses and straight edge*) of Dürer's text *Underweysung der Messung* (*Instructions for measuring*) (76 □). The most common form of compass was the dividers which, unlike the marking compass, was not equipped with a pencil lead or a metal stylus and was used mainly to measure off distances. An example can be seen on the desk in Leonardo's portrait of Luca Pacioli (78 □) and in the hands of Dürer's figure *Melancholia* (80 □). The compass is also an attribute of architects, sculptors, and goldsmiths, who used it to transfer measurements. It appears as a memorable symbol in the hands of the Christian God of Creation, in the Freemasons' emblem, and in the national emblem of the now-defunct German Democratic Republic. Leonardo's manuscripts contain several model designs for compasses (*Paris MS H*, fol. 108v).

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80. □ Albrecht Dürer. 1514. *Melencolia I*.
Städel Museum, Graphische Sammlung, Frankfurt am Main. Inv.: 33377
Engraving
24.2 x 18.9 cm
Reproduction

Image:
08.02.02.05

This engraving, probably Dürer's most famous, is, as an enigmatic "thought picture," dedicated to a representation of melancholy, the somber temperament associated with the god and the planet Saturn, and traditionally also with artists. The personification of this somber temperament broods idly and yet with great concentration, resting her head on her clenched fist. The book in her lap and the compass in her hand lie unused, along with all the other mysterious objects around her. The bat presents the title of the engraving against a backdrop of the nocturnal sky lit up by cosmic phenomena. Some of the scattered tools lie around in an odd state of neglect, almost pleading to be used for their craft, whereas the compass and ruler (76 □) and other instruments like the scales and hourglass tell us of Dürer's belief in measurement and numbers as the universal basis of art. Geometric bodies like the sphere and rhomboid, and the magic square of numbers on the wall, also point to the inherent laws of mathematical regularity.

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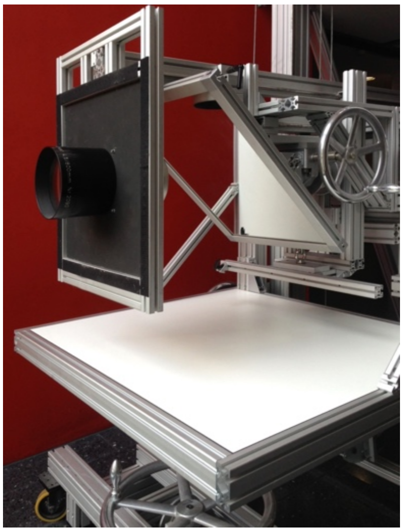
Perspectives

81. □ *Experimentelle historische* Camera obscura *(optical part)*, 2006

Carsten Wirth and Henrik Haag. Max Planck Institute for the History of Science, Berlin
Photo: Montserrat de Pablo Moya

Image:
08.02.03.01 - a



The *camera obscura* (dark chamber) as we understand it today is an optical device consisting of a light-proof box with a tiny aperture (pinhole) through which bundled light rays penetrate and meet on the interior back wall to project an inverted and reversed image. The principle was already known in antiquity. In the early modern age, it was continually refined by adding lenses and mirrors. Artists—especially landscape painters—used the *camera obscura* as a technical aid. Leonardo used the principle to explain how the human eye functioned.

The experimental historical *camera obscura* of the Max Planck Institute for the History of Science is not a copy of a specific historical model but a scientific device that can be configured to match every historical type and is easily adapted for experimental purposes.

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82. □ Leonardo da Vinci. ca. 1508–1509. *Camera obscura*. *Paris MS D*. Institut de France, Paris, fol. 8r

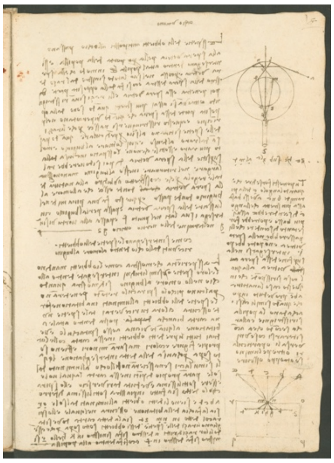
Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS D. Florence: Giunti

Pen and brown ink on paper

22.5 x 16 cm

Image:

08.02.03.01 - b



In *Paris MS D*, which is devoted to the human eye, Leonardo uses an experimental set-up to describe how the eye functions. This phenomenon had been known since antiquity and later, as the *camera obscura*, would form the basis of modern photography. The concentrated light rays of the illuminated object are forced through a tiny opening (*spiraculo*) into a completely darkened space (*abitazione forte scura*). There they can be registered on a sheet of white paper "so that you will see all the named objects … with their shapes and colors, but reduced in size and upside down [and as a mirror image; see the sketch], due to the aforesaid intersection of the rays … when the object is lit by the sun its images (*simulacri*) really seem to be painted on the paper."

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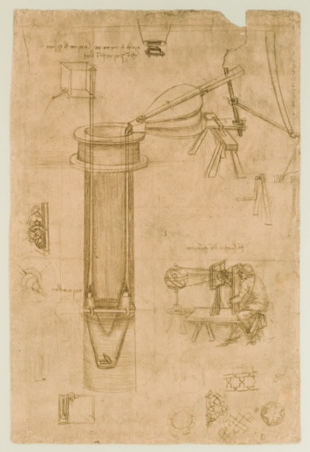
83. □ Leonardo da Vinci. 1478–1482. *Perspective frame*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 5r
Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti
Silver stylus on gray-brown prepared paper
27.6 x 21.6 cm

Image:
08.02.02.02



This sheet, which was probably made while Leonardo was still in Florence, shows several of his early technical designs, including a prominent central drawing of a piston pump driven by bellows. The small sketch on the right demonstrates that, besides mechanics, Leonardo was already intensively concerned early on with the problems of optics and perspective. Here, a draughtsman is occupied with reproducing an armillary sphere (97 □). Its interlaced metal rings can be seen as a perfect exercise in perspective. He meets the challenge with a clever drawing aid. Like Dürer's portrait artist (76 □), he focuses one eye on his object looking through a visor or peephole and then correctly transfers the foreshortenings onto the transparent surface of a perspective frame mounted at the back.

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84. □ Piero della Francesca. ca. 1459–1460. *The Flagellation of Christ*
Galleria Nazionale delle Marche, Urbino. Shelfmark: DE 229
akg-images / Rabatti & Domingie
Tempera on wood
59 x 81.5 cm
Reproduction

Image:
08.02.02.04

Glistening light and an ostentatious mastery of the construction of mathematical perspective characterize this painting by Piero della Francesca, a painter from Borgo San Sepolcro (ca. 1420–1492). How it came to be painted and who commissioned it remain a mystery. The alignments of the visual architectural elements and the coordinate system of the floor reveal the spatial depth used for the visual narrative—but create an irritating effect for the viewer: whereas the action that took place in Pontius Pilate's praetorium is shifted to the far background (a prime example of contemporary palace architecture in the style of Alberti), the viewer's attention is caught by a group of three men on a piazza in the foreground. They are demonstratively untouched by what is happening behind them and "deep in silent conversation." Though mathematically correct, this was a shocking reversal of the scales traditionally used in portraying salvation history, which probably explains the many and often contradictory suggestions as to what it means. So far no one has been able to identify the figures convincingly.

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Platonic Solids

85. □ *Platonic solids, 21st c.*
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Günter Herrmann Lehrmittel. Plexiglass

Image:
08.02.03.02 - a

Platonic solids, named after the Greek philosopher Plato, are defined as convex polyhedra with maximal symmetry. They are constructed out of several congruent regular polygonal faces. Five Platonic solids exist, defined by the number of their faces: tetrahedron (consisting of four triangles), hexahedron = cube (six squares), octahedron (eight triangles), dodecahedron (12 pentagons) (78 □) and icosahedron (20 triangles). In Plato's dialogue *Timaios* they represent the four classical elements fire, earth, air, and water, together with the fifth element, the "quintessence" (celestial ether).

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86. □ After Luca Pacioli and Leonardo da Vinci. 1498. *De divina proportione*. Plate XXXVI, (*Rhombicuboctahedron*). Biblioteca Ambrosiana, Milan, fol. 109r
Pen and brown ink, gouache, watercolor over traces of leadpoint on vellum
25.8 x 20 cm
Reproduction

Image:
08.02.03.02 - b

Geometric solids and their properties were a major area of interest for Leonardo's friend and mentor Luca Pacioli. This splendid manuscript edition of Pacioli's *De divina proportione* (75 □) devotes 60 full page plates to illustrations of these solids based on drawings by Leonardo da Vinci. Aside from the five Platonic solids, it includes Archimedean solids such as the rhombicuboctahedron shown here. The solids are depicted in two different forms, with a closed surface (*planus solidus*) and as an openwork skeletal structure (*planus vacuus*). The same solid, hanging on a fine thread and made of 18 squares and six triangles, also appears in Jacopo de' Barbari's portrait of Pacioli (78 □), but is shown there as a crystalline structure with wafer-thin surfaces that could only be expressed in concrete form back then with the aid of painting.

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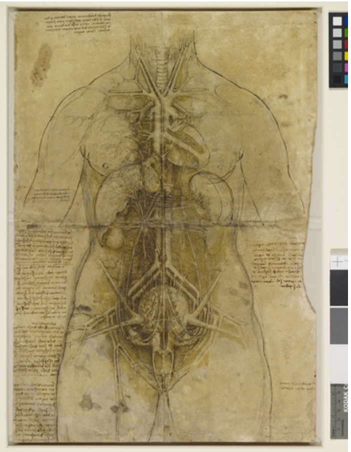
Anatomy and Surgery

87. □ Leonardo da Vinci. ca. 1508–1509. *Atlas of the female anatomy. Corpus of the Anatomical Studies*, fol. 122r
Royal Library, Windsor. Inv.: RCIN 912281

Black and red chalk, pen and ink, yellow wash on toned paper, pricked through
47.6 x 33.2 cm
Reproduction

Image:
08.02.02.01



Leonardo's ideas of the human body as a microcosm later inspired the apt description of this impressive sheet: "Atlas of the female anatomy." In a sense it represents the sum of Leonardo's anatomical studies and illustrates his aspiration to authority in this branch of science. His choice of what was an unusually large format already aligned him with the illustration plates in contemporary anatomical manuals (77 □), although he far exceeded them with his gifts of sharp observation and naturalistic representation. From the viewpoint of modern knowledge, not all the details are correct. The rather oversized ligaments around the uterus, for example, were possibly borrowed from the dissection of a cow.

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88-a. □ ***Surgeon's instruments. 21st c.***
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Replica

Image:
[08.02.03.03 - a]

88-b. □ Brunschwig, Hieronymus. 1497. *Dis ist das buch der Cirurgia, Hantwirchung der wund artzny*. Strasbourg: Grüninger
Sheet XIX, Von den instrumenten
Bayerische Staatsbibliothek Munich. Shelfmark: 2° Inc.c.a. 3452. urn:nbn:de:bvb:12-bsb00026460-6
30 x 22 cm
Reproduction

Image:
[08.02.03.03 - b]

Surgical operations in the Middle Ages and the early modern period were not performed by academically trained physicians but instead, especially in the wider population, by surgeons who were also called shearers, or military surgeons in the armed forces. Sometimes shavers, the predecessors of the later barbers, performed operations as well. They used simple instruments like knives, scissors, and bone saws for amputations. Illustrations of these instruments appear with various enema syringes and a hot water bottle in the surgeon’s manual by the surgeon Hieronymus Brunschwig (ca. 1450–1512). His book is largely based on the *Chirurgia magna* by Guy de Chauliac (ca. 1298–1368), a copy of which was in Leonardo’s library (4 □). Even simple operations were often fatal due to infected wounds caused by lack of hygiene. Leonardo used similar instruments to dissect corpses for his anatomical studies.

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The World, Great and Small

The ancients called man a world in miniature, and that is well-said, because indeed man is made of earth, water, air, and fire, and thus his body is like the Earth. Just as man has bones as a support and framework for his flesh, so the world has stone to support the Earth …
Leonardo da Vinci
Paris MS A, fol. 55v. Translation: Amanda DeMarco

Visual arts, science, and technology were closely intertwined in 15th-century Italy. At the same time, the individual disciplines were part of the evolution of a more comprehensive worldview and the intensive exploration of the relationship between the macrocosm and the microcosm.

The worldview at large continued to rely on the geocentric tradition handed down from antiquity, with the Earth as the center of the universe. The steady growth of knowledge, due not least to the geographical insights gained by voyages of discovery, increasingly called this view into question. In addition, intensified studies of nature in general and of the human body in particular, expanded knowledge of the world on the small scale.

It was hoped that this would lead not only to advances in science, medicine, and artistic representation, but also to a deeper understanding of the fundamental principles of life. The quest for such knowledge of nature was a central motif in Leonardo da Vinci's creative work. The rapid development of printing continually increased the knowledge sources available to the artist-scientist, facilitating his search for an integrative worldview. At the same time, he was able to help shape this worldview through his own contributions: on a small scale through his analytical studies of the human body, and on a large scale through maps and depictions of astronomical phenomena.

Locomotor system (115)

Leonardo’s Berlin Library: Section 9

89. □ Strabo. 1510. *De situ orbis*. Translated by Guarinus Veronensis and Gregorius de Tipherno. Venice: Philippo Pincio
Title page
Max Planck Institute for the History of Science, Berlin. Shelfmark: 2° Rara S8945d

Image
09.01.01.02

The *Geographia* by Strabo (63 BCE–23 CE) is a description in 17 books of the known world of the time—from the Mediterranean area to Africa and parts of Asia, and on to Britain. Unlike Ptolemy’s mathematically oriented *Cosmographia* (90 □), it contains no maps and is entirely text-based, with extensive geological, ethnographical, and historical explanations. Although it is not mentioned in Leonardo’s book lists, some of his ideas about the geology of the Mediterranean region in the *Codex Leicester* derive from the *Geographia*. The title page emphasizes the authority of the ancient geographers with an update: it shows a typical academic scene from the 15th century with Strabo as the instructor at the lectern, surrounded by keen students taking notes.

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Tabula sexta

Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 2° Inc 2661

Photo: Hagen Immel

Image:

09.01.01.03

The early humanists rediscovered Ptolemy's *Cosmographia* in a Greek codex and brought it to Florence, where Iacopo Angeli da Scarperia translated it into Latin in 1406. Some individual manuscripts were expanded with accurate cartographical representations, and these illustrations make the first incunabulum particularly valuable. Leonardo noted the work in his book lists (4 □) and used it mainly as a model for a treatise on anatomy he planned to publish (115 □). The plates showing the human body (the "little world" or microcosm) were intended to resemble those of Ptolemy's *Cosmographia* ("*la cossmografia del mijnor / mo[n]do col medesimo ordijne che … fu fatto da ttolomeo nella cossmografia,*" Royal Library, Windsor, RCIN 919061r).

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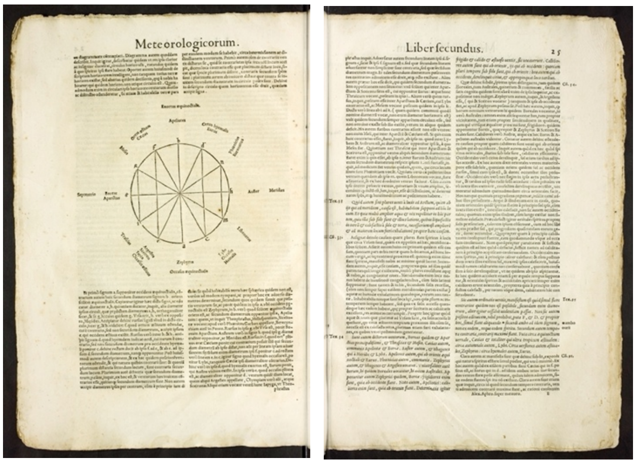
91. □ Alexander <Aphrodisiensis>. 1548. *Alexandri Aphrodisiensis maximi peripatetici, In quatuor libros meteorologicorum Aristotelis, commentatio lucidissima, Alexandro Piccolomineo interprete*. Venice: Scotus
Sheets 24v–25r
Max Planck Institute for the History of Science, Berlin. Shelfmark: 2° Rara A374i

Images:
09.01.01.05 - L
09.01.01.05 - R



The work *Meteora* by Aristoteles (384–322 BCE) (41 □) comprises four books in which he examines phenomena like the elements air and water, in other words, the atmosphere in the widest sense. It deals with meteorological phenomena like clouds, precipitation, winds, and the relationship between land and sea, as well as earthquakes. Leonardo's interest in the macrocosm also covered these topics, and as early as around 1490 he made lists of desirable book titles including a vernacular translation of the "*meteura d'Aristotile vulgare*" (*Codex Atlanticus*, fol. 611 a.r; 4 □). The edition shown here is a commentary of the Aristotelian text by its leading Greek commentator, Alexander of Aphrodisias (2/3 c. CE) in the Latin translation by the Sienese astronomer Alessandro Piccolomini. The diagram gives an overview of the most important winds in the Mediterranean region and their paths.

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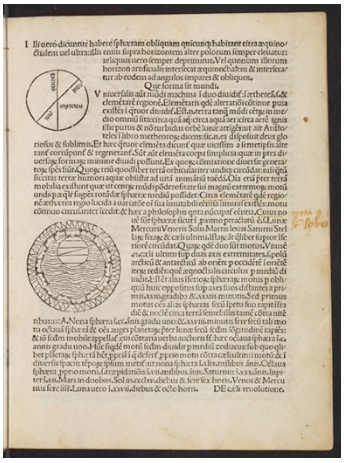
92. □ Sacrobosco, Johannes de. 1490. ***Sphaerae mundi compendium foeliciter inchoat*****. Venice: Octavianus Scotus**
Sheets a6v–a7r
Max Planck Institute for the History of Science, Berlin. Shelfmark: 4° Rara J655sm

Images:
09.01.01.01 - L
09.01.01.01 - R

The treatise *Tractatus de sphaera* or *Sphaera mundi* by the English astronomer and mathematician John of Holywood or Johannes de Sacrobosco (1195–1256), is a four-volume compilation of knowledge about ancient and medieval astronomy. It was used as a standard textbook of cosmology into the 17th century. In his book lists from 1495 (3 □) and 1503/04 (4 □), Leonardo recorded a "*spera*" or "*spera mundi,*" which probably referred to Sacrobosco's work. Moreover, in a definition of the sphere in the *Codex Atlanticus,* he seems to draw on passages from this work. The double page shown here explains the model of the spheres with the aid of a diagram: At the center is the Earth, surrounded by the sublunar spheres of the elements (water, air, fire) followed by the seven planetary spheres, the spheres of the fixed stars, and finally the outer spheres, the *secundum* and *primum mobile*.

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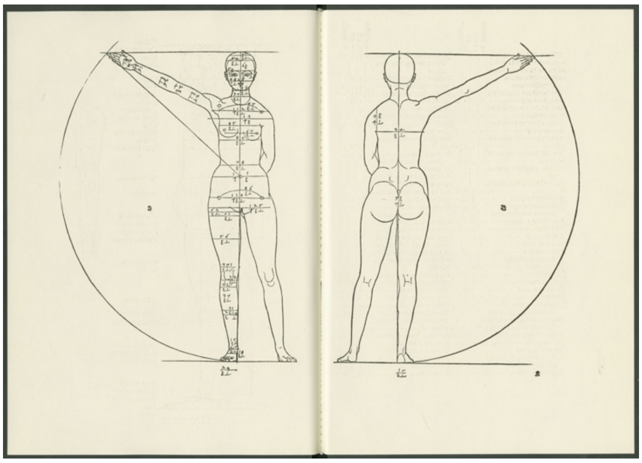
93. □ Dürer, Albrecht. 1528. *Vier Bücher von menschlicher Proportion*. Nuremberg: Hieronymus Andreae
Reprint: 1996. Nördlingen: Uhl
Sheets k1r–k1v
Max Planck Institute for the History of Science, Berlin. Shelfmark: Sou 2 D853h

Image:
09.01.01.04



Like Leonardo, from 1500 onward Albrecht Dürer made an intensive study of anthropometry, the measurement and typical ideal proportions of the human body. Dürer's starting point was the writings of Vitruvius (31 □) and Pliny (52 □). In his posthumously published proportion theory, he provided an introduction to the construction of different body types by assigning specific dimensional ratios to individual limbs. Dürer—unlike Vitruvius—developed proportional schemata not only for the male but also for the female body and the body of a child. In doing so, he decisively transcended the limits of the ancient authorities. An important didactic element on the visual level is that the book is illustrated throughout with exceptionally powerful and accurate woodcut diagrams. While Dürer tried to combine the visual arts with the "leading science" of mathematics, his texts were always aimed at practitioners, artists, and craftsmen to whom he wanted to make ancient and contemporary knowledge accessible in the vernacular.

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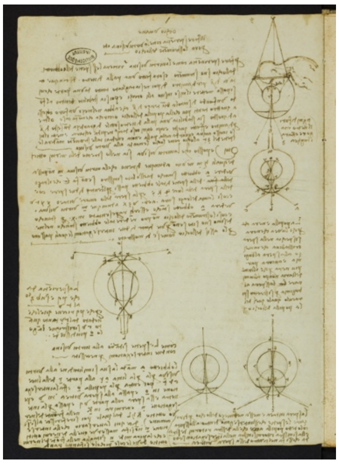
Near and Distant Views

94. □ Leonardo da Vinci. ca. 1508–1509. *Optical experiment*. *Paris MS D*. Institut de France, Paris, fol. 3v

Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS D. Florence: Giunti
Pen and brown ink on paper
22.5 x 16 cm

Image:
09.02.02.01



Leonardo's late text *On the Human Eye* (*dellocchio vmano*) is written partly as a dialogue (in the form of argument and counterargument) on the sense of sight, and presents numerous experiments on optical phenomena. The curious experimental set-up described at the top righthand side with the explanatory drawing is supposed to illustrate how visual perception (*virtù visiva*) functions by means of the eye as an "instrument" or, in Leonardo's words, how the optic rays emanated by the object are registered by the sense of sight. To this end, the test subject is supposed to immerse their own eyes in a model eye. This is simulated by a tinted glass globe filled with water (*uvea*), a box at the bottom with an opening corresponding to the pupil, and an inner sphere of thin glass in place of the lens.

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09.02.02.02

95. □ Leonardo da Vinci. ca. 1506–1508. *Sun and moon*. *Codex Leicester*. Collection of Bill and Melinda Gates, Seattle, WA, MS Leicester 699, fol. 1r

Pen and brown ink over black chalk on paper

28 x 22 cm

Image:

09.02.02.02

The *Codex Leicester* is one of Leonardo's most original research achievements. Besides systematic studies on the topic of water, it contains his extensive reflections on cosmology. The sheet here is devoted to the appearance of the sun (upper diagram) and moon (bottom diagram) and how they are seen from the Earth as viewed from different locations. In another note, Leonardo reminded himself to determine both the distance between the sun and the Earth and to discover the size of the latter. The diagram on the left illustrates his refutation of an imaginary adversary who advocated the thesis that the moon had a metallically reflecting surface and not, as Leonardo liked to think, a fluid one.

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96. □ Leonardo da Vinci. ca. 1510–1512. *Turbulence. Studies on the flow of water*
Royal Library, Windsor. Inv.: RCIN 912660v
Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021
Pen and brown ink, black chalk on paper
29 x 20.2 cm
Reproduction

Image:
09.02.02.03

Among Leonardo's most original scientific contributions were his minutely detailed observations on the movement of water, which were intended to comprise a large part of his planned treatise on the subject (*Libro dell'acqua*). His mastery of the medium of drawing enabled him to demonstrate the most complex dynamic processes and the mechanical forces at work here in the form of an ornamental diagram of lines of force. At the same time, it gave free rein to astonishing aesthetic qualities. The center of the sheet shows the vortex movements and the formation of bubbles that result from the stream of water constantly hitting the water surface. It also shows the effects of obstacles on the water flow in the form of wooden planks in different positions. At the bottom edge of the sheet, Leonardo made a later addition, as he often did: an observation on the flow of water around a ship's bow.

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97. □ Charles François Delamarche. *Geocentric armillary sphere*, Paris, ca. 1800
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Inv.: Kart. B 2840
Photo: Anka Bardeleben-Zennström
Pasteboard with applied engravings, wood, metal
ca. 30 x ca. 45 cm (dia. x h)

Image:
[09.02.03.01](09.02.03.01)

The armillary sphere, named after the Latin word *armilla* (bracelet), and also called the "world machine," is not a measuring instrument but an object for astronomical demonstration to illustrate the motion of celestial bodies. Developed in antiquity and mediated through the Islamic world, it became the hallmark of astronomers and the main symbol of the cosmos in the 15th century. This late specimen made by the French cartographer Charles François Delamarche (1740–1817) is an everyday object made of cheap materials with obvious marks of wear and tear, and generally differs little from its predecessors in earlier centuries. In the center is the fixed globe of the Earth encircled by the solar and lunar disks on metal brackets. Then comes the movable pasteboard ring sphere that depicts the equator, ecliptic (solar orbit), the tropics, and polar circles, and can be adjusted according to the geographical latitude of the location. Although the geocentric image of the world has long been obsolete, the object clearly retains great educational value. Its maker also wrote a practical guide on the use of spheres and globes.

REFERENCES

Nolte, Friedrich. 1922. *Die Armillarsphäre*. (Diss.). Abhandlungen zur Geschichte der Naturwissenschaften und der Medizin 2. Erlangen: Mencke.

98. □ *Astrolabe*, ca. 1980

Loaned by Stiftung Deutsches Technikmuseum Berlin, Stiftung Planetarium Berlin. Inv.: 1/1990/0528 000
Photo: Yvonne Rischke, Kiwi-Foto
Brass, steel, protective lacquer
27 x 5 cm (dia. x d)
Replica

Image:
09.02.03.02

For a long period the astrolabe was the most important working instrument for astronomers. Probably in use as early as antiquity, it was developed further by Arab astronomers around 800 CE and was then used throughout the European Middle Ages until the mid-17th century. Less a measuring instrument than a combination of analog calculator and rotatable star chart, it enabled a large number of widely different and complex applications such as measuring time, calculating dates, and determining locations or elevations. Made of superimposed rotatable layers that represent a stereometric projection of the celestial sky, it can be explained as a two-dimensional armillary sphere. A picturesque legend about the astrolabe says that it originated from a celestial globe that the astronomer Ptolemy dropped while riding a mule that was then trodden flat by the animal.

REFERENCES
Saunders, Harold H. 1984. *All the Astrolabes*. Oxford: Senecio.

The Mobility of Knowledge

Wisdom is the daughter of experience
Leonardo da Vinci
Codex Forster III, fol. 14r

The knowledge gathered by Leonardo in his personal library is collective knowledge. It is based, first, on a long tradition dating back to antiquity, and second, on increasing human mobility since the late Middle Ages. Oceanic navigation and the growth of printing created another major push. Merchants traveled along the major trade routes and maintained branches in important urban centers; participants in the Crusades brought knowledge to Europe, especially from the Arab world; international scholars and students exchanged ideas at the universities thanks to the universal language of Latin; artists and master builders traveled across Europe and beyond in search of lucrative commissions and the latest artistic developments. Explorers on voyages of discovery undertook daring expeditions to hitherto unknown continents and brought back new knowledge, while the colonizers who followed them seized the newly discovered territories—with terrible consequences. This new knowledge was recorded and published in the form of reports, stories, in increasingly precise geographical maps, and in new scientific treatises. The result was a constant expansion of the worldview. In Leonardo's library, too, the share of this new knowledge continued to grow over the years.

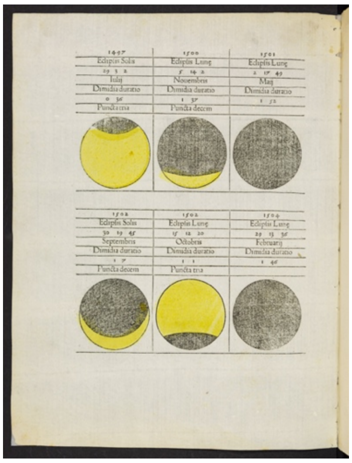
Aerial screw **(109)**

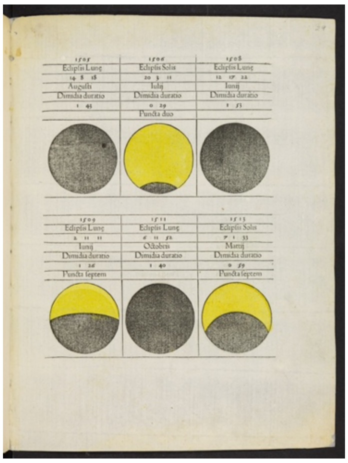
Leonardo’s Berlin Library: Section 10

99. □ Regiomontanus, Johannes. 1476. *Kalendarium*. Venice: Erhard Ratdolt, Bernhard Maler, and Peter Löslein

Sheets 28v–29r
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3767
Photo: Marvin Müller

Images:
10.01.01.01 - L
10.01.01.01 - R





The *Calendar* compiled by Regiomontanus (1436–1476), who came from Königsberg in Bavaria (hence the Latin form of his name), is far more precise than its precursors. Leonardo probably owned an Italian version of it. Aside from a monthly calendar in the typical almanac form, with astronomical data and overviews with forecasts of solar and lunar eclipses for the years 1475–1530, the calendar contains tables showing the expected degree of darkness and a conversion table with Nuremberg as the central reference point of the astronomical data for other European cities. Finally, the author presents an improved method for calculating the date of Easter—one reason for Regiomontanus’ appointment to Rome to work on the calendar reform planned by Pope Sixtus IV. Another work by Regiomontanus, the *Ephemeriden* (*Ephemerides* – calculated predictions for celestial bodies), was the precondition for the exploration of the world (109 □). Columbus, for example, used this as a navigational aid on his voyage of discovery.

REFERENCES

Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 4: *Scholarly Apparatus to Volumes One, Two, and Three*. 4 vols. New Haven / London: Yale University Press, 18.

Mett, Rudolf. 1996. *Regiomontanus. Wegbereiter des neuen Weltbildes*. Einblicke in die Wissenschaft. Wissenschaftsgeschichte. Stuttgart / Zurich: B.G. Teubner / Vdf Hochschulverlag an der ETH.

100. □ Apian, Petrus and Rainer Gemma Frisius. 1548. *Libro dela Cosmographia*. Antwerp: Bontius
Sheets I5v–I6r
Max Planck Institute for the History of Science, Berlin. Shelfmark: 4° Rara A642l

Image
[10.01.01.02]

In 1524—a few years after Leonardo's death—Petrus Apian (actually Peter Bienewitz, 1495–1552), who came from Leisnig in Saxony, published the first edition of his *Cosmographicus Liber*, which clearly followed the tradition of Ptolemaic geography. By the end of the 16th century, this important work for navigational theory, particularly the version edited by the Dutch author Gemma Frisius (actually Jemme Reinersz), had been reprinted in over 30 editions and numerous translations. The copy shown here was the first Spanish edition, printed in the international port of Antwerp. It includes a world map with the heart-shaped projection developed by Apian.

REFERENCES

Röttel, Karl, ed. 1995. *Peter Apian. Astronomie, Kosmographie und Mathematik am Beginn der Neuzeit.* Exhibition catalogue Ingolstadt, 7.10.–12.11.1995. Buxheim-Eichstädt: Polygon-Verlag.

101. □ Fra' Mauro. ca. 1450. *Mappa Mundi*.
Biblioteca Nazionale Marciana, Venice. Shelfmark: 106173
akg-images / Album / Oronoz
Handwritten parchment mounted on wood
223 x 223 cm, map: 196 x 193 cm
Reproduction

Image:
10.02.02.02

This monumental hand-drawn map of the world by Fra' Mauro (died 1459) from the Camaldolese monastery of San Michele in Murano near Venice is the most important and graphically ambitious record of Western cartography from the time just before transoceanic discoveries began. While Ptolemy's *Cosmographia* (90 □) remained the basis for the worldview, innumerable commentaries show that people were rethinking the ideas of this ancient authority. At the same time, there was a demand for integration of new data from recent nautical maps, eyewitness accounts, or travelogues. This is evidenced by the extremely precise mapping of the Mediterranean region, the detailed knowledge of the Asian countries, and the depiction of the west coast of Africa, which was based exclusively on the reports of Portuguese voyagers and showed beyond doubt the African continent could be circumnavigated. In contrast, the map follows the tradition of medieval theology by placing the four cosmological schemata in the outer corners.

REFERENCES

Cattaneo, Angelo. 2011. *Fra Mauro's Mappa Mundi and Fifteenth-Century Venice*. Terrarum Orbis 8. Turnhout: Brepols.

Falchetta, Piero. 2006. *Fra Mauro's World Map*. Terrarum Orbis 5. Turnhout: Brepols.

Vogel, Klaus Anselm. 2011. "Fra Mauro und der moderne Globus." *Der Globusfreund*, no. 57/58: 83–94.

102. □ Martin Waldseemüller. 1507. *Universalis cosmographia secundum Ptholemaei traditionem et Americi Vespucii alioru[m]que lustrationes*

Library of Congress Geography, Map Division, Washington, D.C. Shelfmark: G3200 1507.W3
Woodcut
128 x 233 cm
Reproduction

Image:
10.02.02.01

The Waldseemüller Map is named after its maker, the cartographer Martin Waldseemüller (ca. 1472/75–1520), who came from Freiburg and worked in Saint-Dié in Lorraine. It is often described as "America's birth certificate." This is the first world map to represent the newly discovered landmass in the West as an independent continent and to give it the name "America." It was named after the Florentine navigator Amerigo Vespucci (1454–1512) (104 □), whose travelogue *Mundus Novus* (1502) deeply impressed Waldseemüller. At the top of the map, a portrait of Vespucci is shown beside a miniature depiction of the New World, while the ancient Greek cosmographer Ptolemy figures as a kind of patron of the Old World. The map, which comprises 12 individual sheets, is the only surviving specimen from around 1,000 original copies. There is also an accompanying text on the world map and a segmental map of the globe, one of only a handful of copies still in existence today.

REFERENCES

Lehmann, Martin. 2010. *Die "Cosmographiae Introductio." Matthias Ringmanns und die Weltkarte Martin Waldseemüllers aus dem Jahre 1507. Ein Meilenstein frühneuzeitlicher Kartographie*. Munich: Meidenbauer.

Lester, Toby. 2010. *Der vierte Kontinent. Wie eine Karte die Welt veränderte*. Berlin: Berlin-Verlag.

103. □ Johann Theodor de Bry. 1613. *Das vierdte Buch von der Neuwen Welt. Oder neuwe und gründtliche Historien, von dem Nidergängischen Indien, so von Christophoro Columbo im Jar 1492. erstlich erfunden*. Plate XVIII
John Carter Brown Library, Providence, Rhode Island
Internet Archive, San Francisco
29.5 x 21.5 cm
Reproduction

Image:
[10.02.02.03](10.02.02.03)

The Fourth Book of the New World was published by the Frankfurt publishing house of Theodor de Bry (1528–1598), an engraver originally from Liège, and his successors Johann Theodor de Bry (1561–1623) and Matthäus Merian (1593–1650). Between 1590 and 1634 they published a particularly comprehensive 14-volume anthology of travelogues from the newly discovered continents (which were still generally called the West and East Indies at that time). Aimed at an international readership, they were available in Latin as well as German. The famous fourth volume (first published in 1594) was a new illustrated edition of the *Historia del Mondo Nuovo* by Girolamo Benzoni (1565), based on eyewitness accounts. In his engravings, De Bry, who never visited America, superimposed ethnographical sources with typologies from the European visual tradition. De Bry, a Calvinist, used the opportunity to indict Catholic Spain as a world power, for example, by invoking the biblical scene of the Massacre of the Innocents in Bethlehem in this haunting picture of a massacre by Alonso de Ojeda’s troops.

REFERENCES

De Bry, Theodor. 2019. *America. Sämtliche Tafeln 1590–1602*. Edited by Michiel van Groesen. Cologne: Taschen.

Greve, Anna. 2004. *Die Konstruktion Amerikas. Bilderpolitik in den “Grands Voyages” aus der Werkstatt de Bry*. Europäische Kulturstudien 14. Cologne: Böhlau.

Keazor, Henry. 1998. “Theodore De Bry’s Images for ‘America.’” *Print Quarterly* 2, June (15): 131–149.

104. □ Jan van der Straet/Joannes Stradanus (draughtsman) and Hans Collaert (engraver). ca. 1590. *Astrolabium (Amerigo Vespucci entdeckt das Kreuz des Südens)*. Gr. 2013/67. In *Nova reperta*. Antwerp

bpk / Deutsches Historisches Museum / Arne Psille
Engraving
20.2 x 28.2 cm (sheet)
Reproduction

Image:
10.02.02.04

The Flemish engraver Jan van der Straet (1523–1605), who worked in Florence, presented important inventions and discoveries that were unknown to antiquity in his series of engravings, *Nova Reperta*. They included letterpress printing, spectacles, oil painting—and above all the New World. The discoverer after whom it was named, Amerigo Vespucci, a contemporary of Leonardo's from Florence, is shown here locating the Southern Cross for the first time with the aid of an astrolabe (98 □). The reference to Dante Alighieri doubly underlines the great contribution of people from Florence to discovering the New World—after all, the poet had prophesied the existence of the constellation in the southern hemisphere in the Purgatory section (I, 22ff.) of his *Divine Comedy* (21 □). The atmospheric nocturnal scene is given an extra sacral touch by iconographical reminders of the biblical scene of the Agony in the Garden (Gethsemane) with the wakeful Christ and his sleeping disciples who let him down.

REFERENCES

Baroni Vannucci, Alessandra, and Manfred Sellink, eds. 2012. *Stradanus, 1523–1605. Court Artist of the Medici.* Exhibition catalogue Groeningemuseum, Brügge, 9.10.2008–4.1.2009. Turnhout: Brepols.

Markey, Lia. 2012. "Stradano's Allegorical Invention of the Americas in Late Sixteenth-Century Florence." *Renaissance Quarterly* 65 (2): 385–442.

McGinty, Alice Bonner. 1974. "Stradanus (Jan van der Straet). His Role in the Visual Communication of Renaissance Discoveries, Technologies, and Values." Ph. D., Medford, MA: Tufts University.

Palm, Erwin Walter. 1985. "Amerika oder die eingeholte Zeit. Zum Lob des Vespucci von Joannes Stradanus." In *Gedenkschrift für Gerdt Kutscher 2*, edited by Anneliese Mönnich, Berthold Riese, and Günter Vollmer. Indiana 10. Berlin: Gebr. Mann, 11–17.

105. □ *Behaim globe*, ca. 1491–1494
Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Inv.: Kart. A 6620
Photo: Anka Bardeleben-Zennström
Replica by Greaves & Thomas, 1992. Plaster of Paris globe with paper covering, horizontal brass ring, wrought iron stand
51 cm (dia.), ca. 130 cm (h) with stand

Image:
10.02.03.02

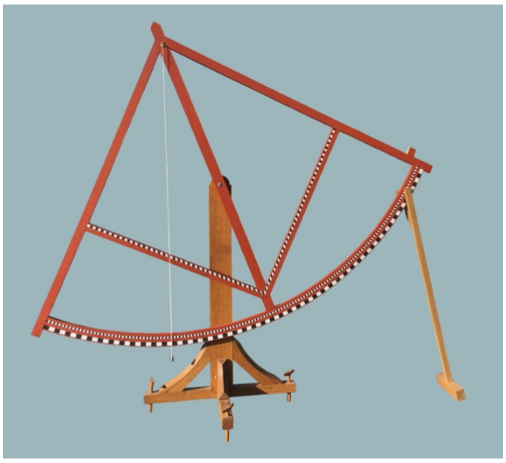
The original version of this globe, also known as the *Erdapfel* (lit. earth apple), is preserved in the German National Museum in Nuremberg. It is the oldest representation of the Earth in the form of a globe. Commissioned by the council of the trading metropolis of Nuremberg, it was designed by the merchant and sailor Martin Behaim (1459–1507). Numerous arithmeticians, artists, and craft workers were involved in its production. A wide variety of sources including ancient authorities such as Ptolemy (90 □), Strabo (89 □), and Pliny (52 □), together with contemporary travelogues and Behaim's own experience, contributed to the encyclopedic depiction with hundreds of pictograms, place names, and descriptions. Precise cartographical representations intermingle with fantastical island kingdoms and exotic mythical creatures. But one can look in vain for the American continent. By the time it was finished, this showpiece, made in the same period as Columbus' voyage of discovery, was already outdated.

REFERENCES

Bott, Gerhard, ed. 1992. *Focus Behaim Globus.* Exhibition catalogue Germanisches Nationalmuseum, Nuremberg, 2.12.1992–28.2.1993. 2 vols. Nuremberg: Germanisches Nationalmuseum.

106. □ *Lindholmer quadrant*, ca. 1600
Privately owned, Stiftung Planetarium Berlin
Photo: Felix Lühning
Replica by Felix Lühning, 2013. Oak wood, beech, brass, steel
Radius of the quadrant 198 cm, stand height 149 cm, foot radius 97 cm

Image:
10.02.03.03



A *quadrans* (the Latin word for a quarter circle) is an astronomical instrument for establishing the height of celestial bodies above the horizon relatively easily. The pendulum quadrant shown here did this with the aid of an aperture diopter and a pelorus set to the upper side. The altitude of the angle was read off by a plumb-line thread moving in front of the arc divided into degrees. A more exact result could be achieved by using a double quadrant with gradations. The value of the scale below divided by the total length of the upright scale above gives the tangent of the measured angle. Like Leonardo, the constructor of this quadrant, the North Friesian pastor Albert Meyer (1528–1603), was not a professional astronomer: he intended to use the instrument for a Greenland expedition (that never actually happened). After he died, it was used as a hat stand in the church at Lindholm until it was finally purchased by the Schleswig-Holstein State Museum.

REFERENCES

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Knowledge Explosion

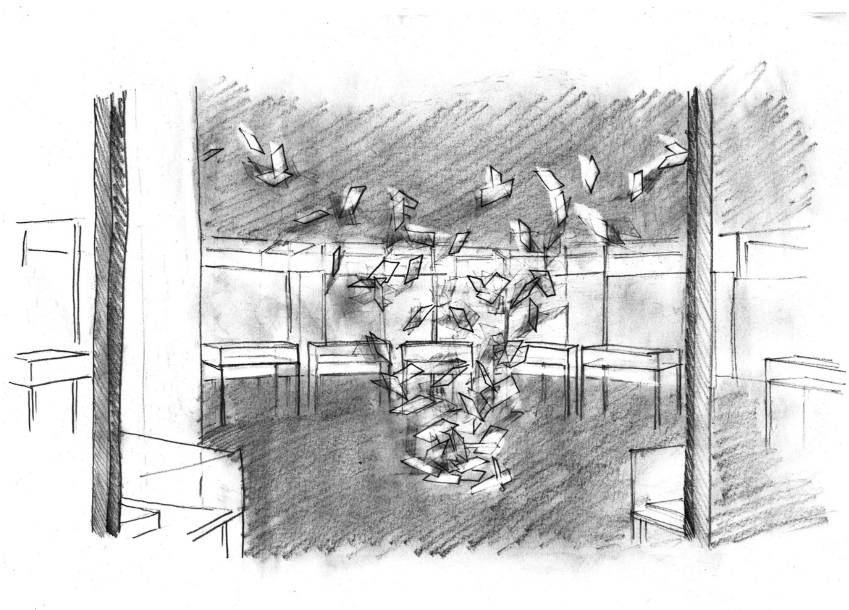
Image: Zentrum_Wissensexplosion

See through the dizzying corridors of the winds great flocks of birds coming from distant lands

Leonardo da Vinci, *Codex Atlanticus,* fol. 981 r c

Future bound the bookish tower
Wings beat against the walls secure
One more word, one more dash

Caught in flight, can it endure?
Knowledge in vessels may easily crash
Rustle, pull, a mind's fierce power



Serge von Arx. 2021. Knowledge Explosion. Sound Sculpture.

Knowledge arises from a combination of new discovery and the interweaving of what has already been achieved. All elements of knowledge must be grasped at their core and repeatedly questioned anew. Only through the liberation from and further development of associations, connotations, rules, and supposedly inherent systems can synergies arise from interconnections that create something new. Individual elements are sometimes less relevant than the way they are linked, in the sense of the resulting added value. Today, in particular, a flood of seemingly ad hoc information often deceives us about the need to contextualize relevant contributions. Changing perspectives, shifting frames, and recontextualizing phenomena are fundamental premises in science, just as they are in art. Knowledge arises from a critical further development of structures that exist in the light of accumulated experience.
Leonardo da Vinci was not only an artist and not just a scientist. Driven by infinite curiosity, he unified both in his observations and in his works. But only the meticulous elaboration of all the individual elements enables a deeper understanding of their interconnectedness.

Important new discoveries often arise, it seems, purely by chance. But this coincidence requires a breeding ground that must be actively created by continually questioning all aspects of knowledge, by stirring up and pursuing all epistemic particles. Leonardo da Vinci was the avant-garde of a systematic disruption of self-contained knowledge structures. An unencumbered and agile mind is the prerequisite of all cognitive achievements; Leonardo's genius arose from precisely that connectedness of human existence.

Epilogue: The Codices

And this is a collection without order, compiled from many papers that I have copied here, hoping to put them in their respective order, according to the subjects they address …
Leonardo da Vinci
Codex Arundel, fol. 1r. Translation: Elizabeth Hughes

Leonardo's surviving literary estate comprises over 4,000 sheets; a total of 22 volumes of illustrated manuscripts, generally known as codices, still exists today. The material is extremely heterogenous. Alongside pocket-sized sketchbooks with jottings made on the spot purely for his own use, there are large-format clean copies that seem to address an audience. What the volumes have in common is their thematic diversity, and all show traces of continual use and revision. At his death, Leonardo left the volumes to his collaborator and heir Francesco Melzi (1491/92–1567). Melzi's heirs sold a large part of this legacy to the sculptor Pompeo Leoni (ca. 1533–1608). In 1637 the collector Galeazzo Arconati (before 1592–1649) donated several of these manuscripts to the Biblioteca Ambrosiana in Milan. They ultimately reached Paris as part of Napoleon's spoils of war where most of them are still kept today—fortunately mostly in their original binding. Other codices took entirely different paths—though under similarly dramatic circumstances.

107. □ Leonardo da Vinci. 1505. *Transformation*. *Codex Forster I*. Victoria and Albert Museum, London, fol. 7r
Reprint: Marinoni. 1992. I Codici Forster del Victoria and Albert Museum di Londra
Florence: Giunti
Pen and brown ink on paper
14.5 x 10 cm

Image:
11.02.01.01

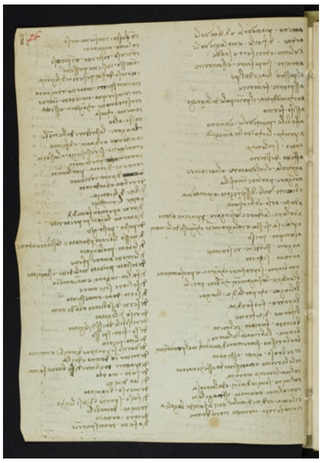
A connected series of sheets testifies to Leonardo's intensive study of the problems of spatial geometry (stereometry) based on Euclid's *Elements* (12 □). It is signed self-confidently with the words, "started on July 12, 1505 by me, Leonardo da Vinci" (fol. 3r), and he probably intended to expand it into a treatise in its own right. Here it deals almost exclusively with exercises that the artist works through on the transformation of the shape of geometric bodies of constant volume. He explains step by step his procedure for the transformation of a dodecahedron into a cube of the same volume. To heighten its didactic value, he illustrates the most important interim stages of the construction with a neatly numbered sequence of pen drawings.

REFERENCES

Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 460–464.

108. □ Leonardo da Vinci. ca. 1487–1490. *Vocabulary*. *Codex Trivulzianus*. Biblioteca Trivulziana, Milan, fol. 13v
Reprint: Brizio. 1980. Il Codice di Leonardo da Vinci nella Biblioteca Trivulziana di Milano. Florence: Giunti
Pen and brown ink on paper
19.5 x 13.5 cm

Image:
11.02.01.02



A large part of the *Codex Trivulzianus*, one of Leonardo's earliest notebooks, is filled with pages and pages with lists of words (over 8,000 terms), often arranged in several columns. The goal of this diligent exercise was to compensate for the deficiencies of his native vernacular Tuscan dialect by cultivating a written language which, as Cristoforo Landino had advised in the introduction to his Dante commentary (21 □), should be enriched by as many Latin loan words as possible. The sources Leonardo used, aside from poetic works and specialist technical literature, included exemplary, alphabetically arranged thesauruses like the *Vocabolista* by the Florentine poet Luigi Pulci (1432–1484). From this, Leonardo copied terms and their meaning, from "*ameno*" (pleasant/agreeable) to "*diafano*" (transparent), to fol. 13v (shown here, from right to left).

REFERENCES

Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 88–91.

Fanini, Barbara. 2018. *Le liste lessicali del codice Trivulziano di Leonardo da Vinci. Trascrizione e analisi linguistica*. Filologia e ordinatori 34. Florence: Franco Cesati Editore.

———. 2019. "The Library of a 'Man without Letters'." In *Leonardo and His Books. The Library of the Universal Genius.* Exhibition catalogue Museo Galileo, Florence, 6.6.–22.9.2019, edited by Carlo Vecce. Florence: Giunti, 32–41.

109. □ Leonardo da Vinci. 1487–1490. *Aerial screw (propeller)*. *Paris MS B*. Institut de France, Paris, fol. 83v

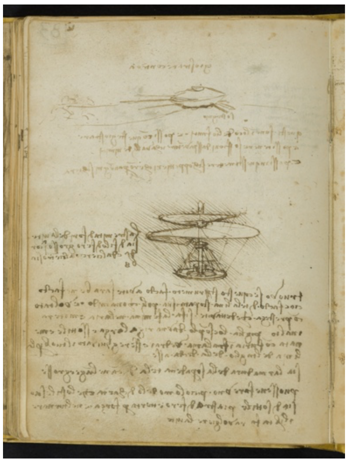
Reprint: Marinoni. 1990. I Manoscritti dell'Institut de France: MS B. Florence: Giunti

Pen and brown ink on paper

23 x 16 cm

Image:

11.02.01.03



This notebook of Leonardo's did more than any other to establish his popular reputation as a man far ahead of his time. This was due not least to his original ideas about mobility, including aircraft like the one shown here, which is often called—not quite accurately—Leonardo's "helicopter." In contrast to the bird-like ornithopter, no models existed for this. It is doubtful whether it was designed to explore the world (99 □) but at any rate its inventor had some ideas for its possible practical use and specified a diameter of around 4.8 meters along with the materials to be employed: reinforced linen and wire. Made with care from these materials and spun quickly, the "(aerial) screw" (*vite aerea*) turned the air itself into a thread and rose upward.

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Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 161–178.

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110. □ Leonardo da Vinci. ca. 1490–1491. *Cast shadows*. *Paris MS C*. Institut de France, Paris, fol. 13r

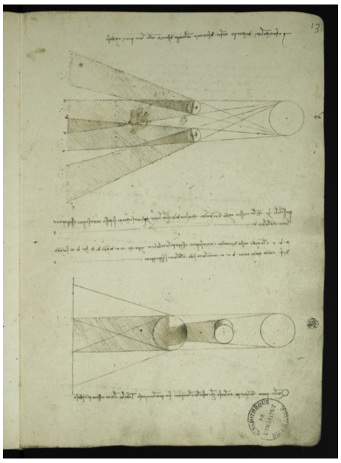
Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS C. Florence: Giunti

Pen and brown ink, wash on paper

31 x 22 cm

Image:

11.02.01.04



Although it also covers other topics as well, this early manuscript is generally called Leonardo's *Book of Light and Shade*. The theme of shadow projection attests to his intensive theoretical study of the tradition of optical treatises (72 □), and at the same time has concrete implications for his practical artistic production. Compared with the other notebooks, this one stands out for its relatively large format, the clean writing, and the carefully made drawings, suggesting it was intended for publication. The expositions are based on Leonardo's systematic experiments with an artificial light source, a candle. He focuses particularly on the color, intensity, and layering of shadows cast by cylindrical or spherical objects.

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Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 111–119.

Kaufmann, Thomas DaCosta. 1975. "The Perspective of Shadows. The History of the Theory of Shadow Projection." *Journal of the Warburg and Courtauld Institutes* 38: 258–287.

Leonardo da Vinci. 2006. *Codice C*. Edited by Manlio Brusatin and Vittorio Mandelli. Carte d'artisti 80. Milan: Abscondita.

111. □ Leonardo da Vinci. 1495–1500. *Problem-solving*. *Paris MS M*. Institut de France, Paris, front inside cover and fol. 1r

Reprint: Marinoni. 1986. I Manoscritti dellʾInstitut de France: MS M. Florence: Giunti
Pen and brown ink on paper
10 x 7 cm + 10 x 7 cm

Image:
[11.02.01.05](11.02.01.05)

Leonardo used these pocket-sized notebooks as workbooks for field studies. He sorted much of their contents and made clean copies which he transferred to larger formats.

He used the notebook shown here mostly as an exercise book for his own study of the foundations of Euclid’s geometry, particularly the third lesson of the first book, as the heading reveals. This provided the starting point for solving advanced geometric problems (35 □). On this double page, Leonardo demonstrated three different kinds of triangles: acute angle, right angle, and isosceles. The unconnected remark “ermete filosofo” refers to the enigmatic writings of Hermes Trismegistos, a group of neo-Platonic books translated by the Florentine humanist Marsilio Ficino, a contact of Leonardo’s from his youth in Florence.

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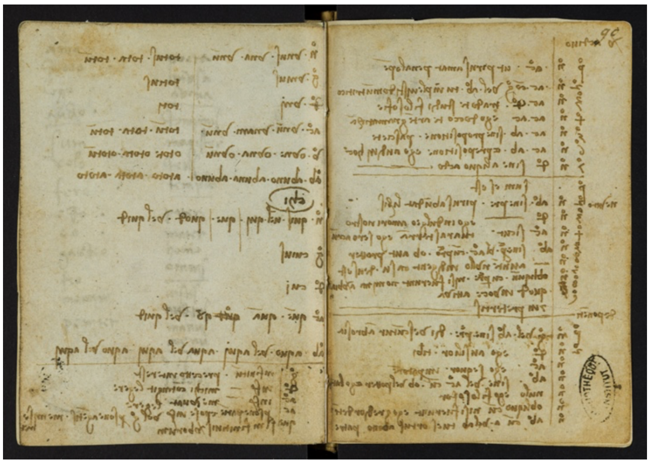
Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 85–86.

Rinaldi, Furio. 2013. *De ludo geometrico. La Matematica e la Geometria di Leonardo. Disegni di Leonardo dal Codice Atlantico.* Exhibition catalogue Biblioteca Ambrosiana, Milan, 10.12.2013–9.3.2014. Novara: De Agostini.

112. □ Leonardo da Vinci. ca. 1497. *Rules of grammar*. *Paris MS I*. Institut de France, Paris, fol. 137v–138r

Reprint: Marinoni. 1987. I Manoscritti dell'Institut de France: MS I. Florence: Giunti
Pen and brown ink on paper
10 x 7.5 cm + 10 x 7.5 cm

Image:
11.02.01.06



Leonardo was over 40 years old when he began teaching himself Latin. This double page shows his method, which is not very different from today's method of memorizing grammatical rules. Written in his typical mirror writing, it is disciplined and clear, working through the declination of nouns case by case (identifiable by the abbreviations from nominative to ablative). Different forms of verbs, for example, are classified according to the classes of verbs based on the system of Niccolò Perotti's *Rudimenta grammatices* (42 □). Memory aids are provided by sample sentences like "*Pirus amat Penalopem*" (Pirus loves Penelope) and "*Ego doceo te artem gramaticam*" (I teach you the art of grammar).

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Findlen, Paula. 2019. "Learning Latin." In *Leonardo's Library. The World of a Renaissance Reader*, edited by Paula Findlen. Stanford, CA: Stanford Libraries, 146–149.

113. □ Leonardo da Vinci. 1502. *Span of a bridge*. *Paris MS L*. Institut de France, Paris, fol. 66r

Reprint: Marinoni. 1987. I Manoscritti dell'Institut de France: MS L. Florence: Giunti
Pen and brown ink on paper
10 x 7 cm

Image [please rotate 180°]:
11.02.01.07

In 1502 Leonardo contacted the Ottoman sultan Bayezid II (1447–1512) with a plan for a bold engineering project: a bridge between the center of Constantinople (now Istanbul) and the city district of Pera. Its design revealed him to be a highly inventive engineer whose skills could match up to the authors of contemporary treatises on military and fortification (63 □). The sketch above shows the aerial view; below this is the elevation of the arched bridge over the Golden Horn, an inlet of the Bosporus. The original construction was designed to be stabilized by outward-facing parabolic struts. As Leonardo stressed in both drawings, the previously unimaginable span of around 238 m (400 *braccia*) and the height of around 42 m (70 *braccia*) would have allowed even a sailing ship to pass underneath easily. The Topkapi Museum in Istanbul contains the Turkish translation of a related letter with further ideas.

REFERENCES

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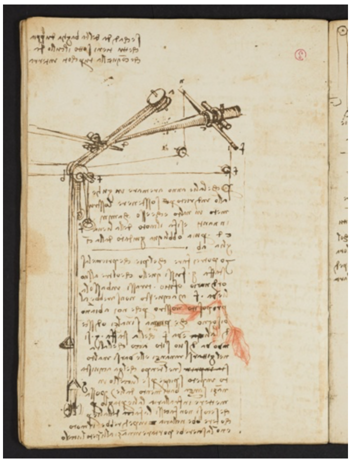
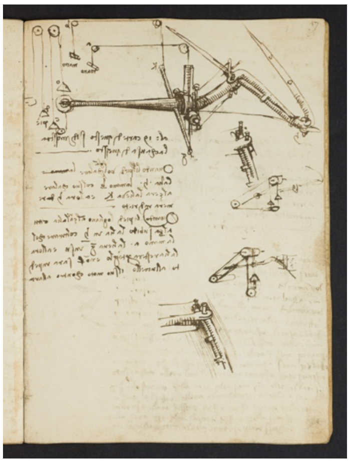
Schettini, Franco. 1972. "Istanbul/Costantinopoli. Un ponte di Leonardo sul Corno d'Oro. Contributo allo studio di un disegno di Leonardo per il ponte sul Corno d'Oro." *Parametro* 10: 68–79.

114. □ Leonardo da Vinci. ca. 1505–1506. *The flight of birds. Codex on the Flight of Birds / Codice sul volo degli uccelli*. Biblioteca Reale, Turin, Cod. Varia 95, fol. 16v–17r
Reprint: Marinoni. 1976. Il Codice sul volo degli uccelli nella Biblioteca Reale di Torino. Florence: Giunti
Pen and brown ink over red chalk drawing on paper
21 x 15 cm + 21 x 15 cm

Images:
11.02.01.08 - L
11.02.01.08 - R

Leonardo was occupied with ideas about the flights of birds and the possibility of humans flying throughout his life. He claimed that while still an infant in the cradle, even before learning the rudiments of reading and arithmetic (16 □) he remembered an encounter with a kite (*nibbio*), the bird of prey whose wingbeat and gliding he later studied and sketched in great detail in natural surroundings. He wrote about this in his earliest memoir of childhood (*Codex Atlanticus*, fol. 186v; analyzed by Sigmund Freud in a famous essay from 1909/10). In the manuscript shown here he transforms his empirical observations into mechanical designs for a flying machine driven by human muscle power (*ornithopter*), with its flight principle modeled on the skeleton of a bird. Leonardo persisted with his empirical studies on aerodynamics even after the failure of practical trials with the “large bird.”

REFERENCES

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Freud, Sigmund. 2000. *Eine Kindheitserinnerung des Leonardo da Vinci*. Frankfurt a. M.: Fischer.

Pedretti, Carlo. 1990. *I disegni di Leonardo da Vinci e della sua cerchia nella Biblioteca Reale di Torino*. Florence: Giunti.

Schapiro, Meyer. 1956. “Leonardo and Freud. An Art-Historical Study.” *Journal of the History of Ideas* 17 (2): 147–178.

115. □ Leonardo da Vinci. 1506–1509. *Locomotor system*. *Paris MS K*. Institut de France, Paris, fol. 109v

Reprint: Marinoni. 1989. I Manoscritti dell'Institut de France: MS K. Florence: Giunti

Pen and brown ink over black and red chalk on paper

9.5 x 6.5 cm

Image [please rotate 180°, as shown here]:
11.02.01.09

Leonardo understood the body as a microcosm, a world in miniature (90 □). In the center of this page are the hips and hind legs of the skeleton of a horse, the very animal that Leonardo had recurrently studied for artistic purposes. The human locomotor system, shown in a nearly identical section and similar stance on the left, yields information by comparing the two systems. Leonardo wrote a note to remind himself to ascertain the differences between humans and horses and all the other animals, and to do this systematically, first for the bones, then for the different muscles and sinews. An unconnected note at the upper edge of the page mentions, as so often, a promising book: At Messer Vincenzo Aliprandi's there was a copy of Vitruvius that had once belonged to the military engineer Giacomo Andrea.

REFERENCES

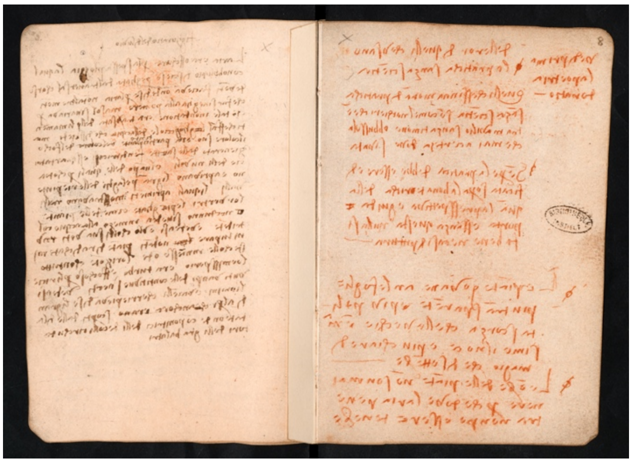
Bambach, Carmen C. 2019a. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press, 487.

———. 2019b. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 147, (145–160).

116. □ Leonardo da Vinci. 1513–1514. *Doomsday*. *Paris MS G*. Institut de France, Paris, fol. 6v, 8r

Reprint: Marinoni. 1989. I Manoscritti dell'Institut de France: MS G. Florence: Giunti
Pen and brown ink on paper (6v); red chalk on paper (8r)
14 x 20 cm + 14 x 20 cm

Image:
11.02.01.10



Particularly in his later years Leonardo propagated an overpowering idea of doomsday, both in drawings and as an epic text like this passage that was probably intended for his book project *Libro di pittura*. Inspired by poetic models like Ovid's *Metamorphoses* (49 □), Leonardo's powerful words evoke the Deluge (“*figuratio[n] del djluvio*”)—but in the sense of natural history, not the Bible. He focuses mainly on the movement of water masses, the trajectory of rainfall that spreads in waves like dust clouds, and the light phenomena produced by ceaseless lightning. He invokes mythological figures, the sea god Neptune, and the god of the winds—Aeolus—while humans, who are completely powerless, are only marginally mentioned.

REFERENCES

Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 456–457, (453–472).

117. □ The codices

Image:
11.02.01.11

Composition: Sabine Bertram and Esther Chen.
Photo: Marvin Müller.

Codex	Designation	Repository
Codex Arundel	*Arundel MS* 263	British Library, London
Codex Atlanticus		Biblioteca Pinacoteca Ambrosiana, Milan
Codex Forster I		National Library of Design, Victoria and Albert Museum, London
Codex Forster II		National Library of Design, Victoria and Albert Museum, London
Codex Forster III		National Library of Design, Victoria and Albert Museum, London
Codex Huygens	MA 1139 Department of Drawings	Pierpont Morgan Library and Museum, New York
Codex Leicester (formerly: *Codex Hammer*)		Collection of Bill and Melinda Gates, Seattle, WA
Codex Madrid I	*Codex Corvinus Matritensis* 8937	Biblioteca Nacional de España, Madrid

Codex Madrid II	*Codex Corvinus Matritensis* 8936	Biblioteca Nacional de España, Madrid
Codex on the Flight of Birds / Codice del volo degli uccelli	*Cod. Varia* 95	Biblioteca Reale, Turin
Codex Trivulzianus	N 2162	Biblioteca Trivulziana, Castello Sforzesco, Milan
Libro di pittura	*Codex Urbinas Latinus* 1270	Biblioteca Apostolica Vaticana, Rome
Paris MS A	Inv. nos. 2172, 2185	Bibliothèque de l'Institut de France, Paris
Paris MS B	Inv. nos. 2173, 2184	Bibliothèque de l'Institut de France, Paris
Paris MS C	Inv. no. 2174	Bibliothèque de l'Institut de France, Paris
Paris MS D	Inv. no. 2175	Bibliothèque de l'Institut de France, Paris
Paris MS E	Inv. no. 2176	Bibliothèque de l'Institut de France, Paris
Paris MS F	Inv. no. 2177	Bibliothèque de l'Institut de France, Paris
Paris MS G	Inv. no. 2178	Bibliothèque de l'Institut de France, Paris
Paris MS H	Inv. no. 2179	Bibliothèque de l'Institut de France, Paris
Paris MS I	Inv. no. 2180	Bibliothèque de l'Institut de France, Paris
Paris MS K	Inv. no. 2181	Bibliothèque de l'Institut de France, Paris
Paris MS L	Inv. no. 2182	Bibliothèque de l'Institut de France, Paris
Paris MS M	Inv. no. 2183	Bibliothèque de l'Institut de France, Paris
Drawings of the *Royal Collection*		Royal Library, Windsor Castle, Windsor

Atlanticus, Scattered

The *Codex Atlanticus*, which has been known by this title since the 18th century because of its large, atlas-type format, is the earliest collector's album with Leonardo's drawings and notes. The sculptor Pompeo Leoni, who had purchased a large part of Leonardo's bound manuscripts, compiled it from over 1,700 individual drawings and sheets of different sizes made on various dates from 1478 to 1518. Leoni stuck them onto huge sheets of paper. The English translation of the title of the original leather-bound volume is "Drawings of machines and secret arts and other things of Leonardo da Vinci." After several major attempts at restoration, the album was finally dismantled in 2008/09. The drawings are now kept in individual picture mounts in line with today's conservation standards.

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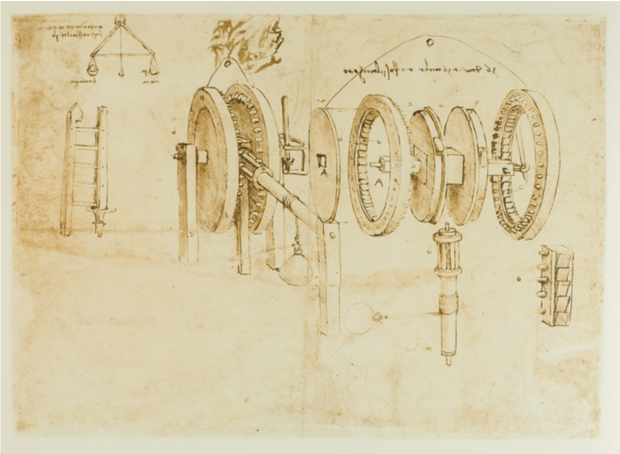
Bambach, Carmen C. 2019. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press, 612–617.

Barberi, Francesco. 1982. "Il restauro del Codice Atlantico di Leonardo da Vinci." *Accademie e Biblioteche d'Italia* 50 (2): 98–111.

Marinoni, Augusto. 1982. "Sul restauro del Codice Atlantico." *Raccolta Vinciana* 21: 9–20.

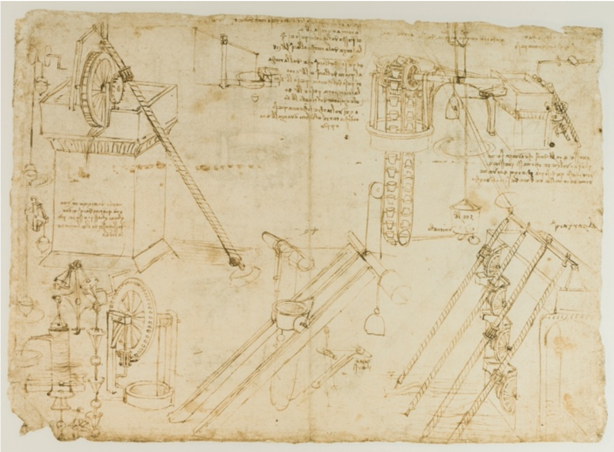
118. □ Leonardo da Vinci. 1478–1480. *Exploded-view drawing of a gear train*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 30v
Reprint: 1973–1975. *Il Codice Atlantico* Vol. 1. Florence: Giunti
Pen and brown ink, wash, black chalk on paper
27.8 x 39 cm

Image:
11.02.03.01 - a



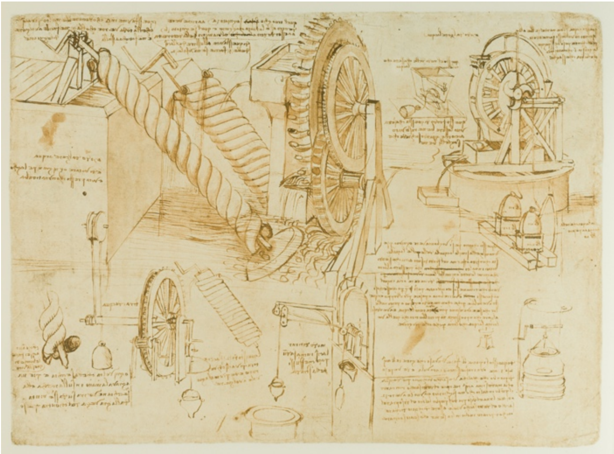
119. □ Leonardo da Vinci. ca. 1480–1482. *Systems for drawing water (bucket chain, Archimedean screw)*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1069v
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Brush, pen, brown ink, wash, black chalk on paper
28.5 x 39.7 cm

Image:
11.02.03.01 - b



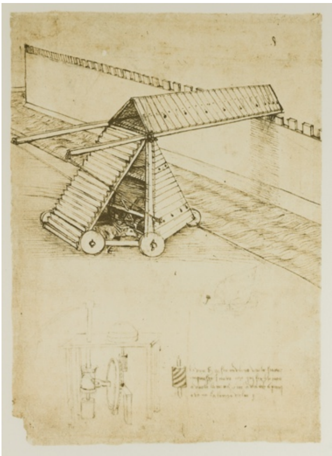
120. □ Leonardo da Vinci. ca. 1480–1482. *Systems for drawing water (Archimedean screw, water wheels). Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 26v
Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti
Pen, brush and brown ink, wash on paper
29.1 x 40 cm

Image:
[11.02.03.01 - c]



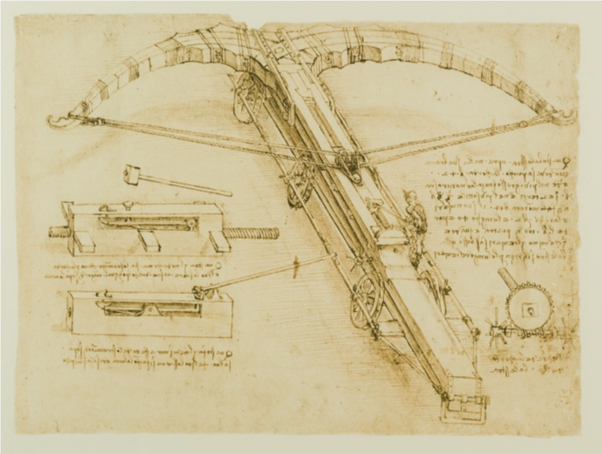
121. □ Leonardo da Vinci. ca. 1480. *Siege engine*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1084r
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Pen and brown ink on paper
27.2 x 19.5 cm

Image:
11.02.03.01 - d



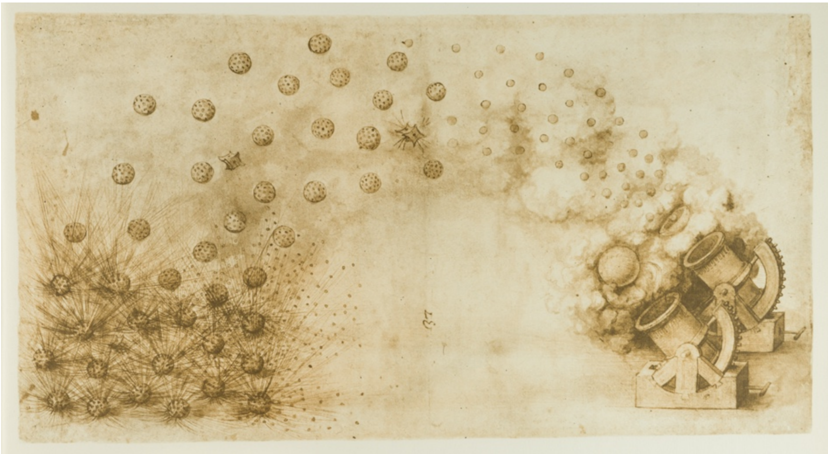
122. □ Leonardo da Vinci. 1485–1492. *Giant crossbow*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 149r (b)
Reprint: 1973–1975. Il Codice Atlantico Vol. 2. Florence: Giunti
Pen and brown ink, wash over black chalk on paper
20.3 x 27.5 cm

Image:
11.02.03.01 - e



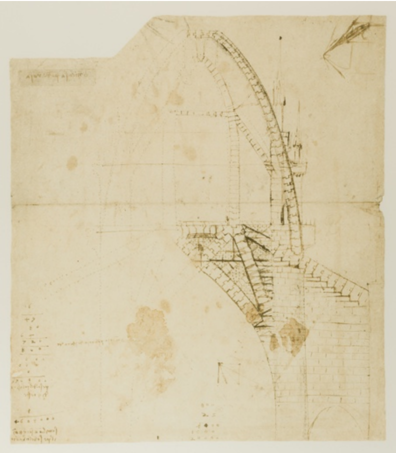
123. □ Leonardo da Vinci. 1485. *Shrapnel mortar*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 33r
Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti
Pen and brown ink, wash on paper
21.8 x 40.9 cm

Image:
11.02.03.01 - f



124. □ Leonardo da Vinci. 1487–1488. *Studies for the domed crossing tower (tiburio) of Milan Cathedral*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 850r
Reprint: 1973–1975. Il Codice Atlantico Vol. 10. Florence: Giunti
Pen and brown ink, some brush, over black chalk, contours partly pricked, on paper
33.2 x 29.3 cm

Image:
11.02.03.01 - g

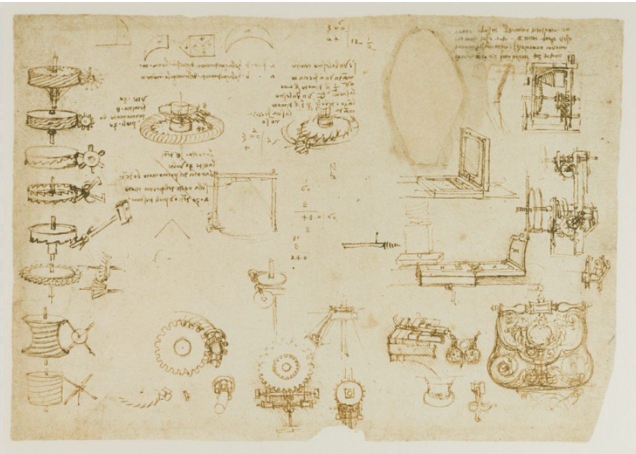


125. □ Leonardo da Vinci. ca. 1487–1490. *Studies of aircraft (parachute)*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1058v
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Pen and brown ink on paper
28.8 x 21.4 cm

Image:
11.02.03.01 - h

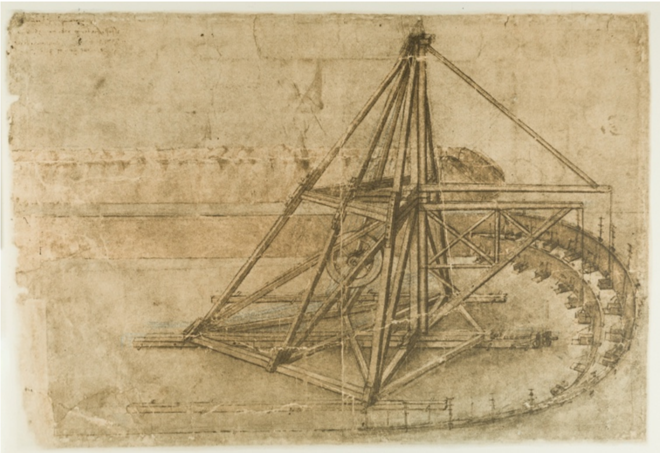
126. □ Leonardo da Vinci. ca. 1497. *Studies on mechanics (jobbing press, gear drive). Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1038r
Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti
Pen and brown ink on paper
19.7 x 28.3 cm

Image:
11.02.03.01 - i



127. □ Leonardo da Vinci. 1503–1504. ***Crane for canal construction*****.** ***Codex Atlanticus*****. Biblioteca Ambrosiana, Milan, fol. 4r**
Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti
Pen and brown ink, wash, on gray-brown lined paper
28 x 40 cm

Image:
11.02.03.01 - l



Epilogue

Leonardo rarely succeeded in finishing his works, such as the painting *The Battle of Anghiari*, his treatise on painting, or a book he planned on mechanics. Much of his work remained mere experimentation, whether in painting technique, in his projects as sculptor or architect, or in his mathematical endeavors. On the other hand, he succeeded in such strokes of genius—just think of his observations of turbulence or his drawings of complex technical relationships—that it was practically impossible for the generation immediately after him to follow his example. Nevertheless, many of his ideas and suggestions—whether in art or science—have had an impact in the long term, if often by convoluted routes.

Leonardo must have been aware of his limited capabilities as an author on a daily basis—for instance, when comparing his own attempts at writing with the works of glacial elegance by a writer like Leon Battista Alberti. Yet Leonardo had a unique eye and an almost unsurpassable curiosity. For him, the journey was often more important than the destination, and the creative process more revealing than its result. Nonetheless, he worked hard to become an author, trying diligently, for example, to elaborate preliminary sketches in one manuscript and refine them for use in another text destined for publication.

Leonardo's notebooks reflect the complex pattern of his thoughts in a manner that resembles the hypertext structure of today's Web more closely than the world of books back then. The notebooks formed a library of their own within his library—they accompanied him on his travels and all through his life, along with his printed books. Paradoxically, his manuscripts participated in the accelerated diffusion of knowledge in the early modern period. Whereas only one single work of his was printed—posthumously—his manuscripts were scattered to the four winds. Who read them, and who was inspired by them? Who reassembled them?

Others who came after him tried to compose his notes into books, from his treatise on painting to the present-day editions of his works. The transmission of his manuscripts in various codices has shaped his legacy. The myth of Leonardo was created against the backdrop of their extremely complex reception history. To this day, this obscures our view of the roots of his work in the great acceleration of the 15th century—but also its significance as a distant mirror of our world in upheaval today. What did the genius Leonardo create out of the collective knowledge of his time? Precisely how has his oeuvre continued to have an impact? And what can we still learn today from his way of dealing with the challenges of his time? These are the real riddles of the "da Vinci code" inscribed in his intellectual cosmos.

Leonardo Pop

Who thinks little, errs much
Leonardo da Vinci
Paris MS H, fol. 119r

Images:
Folder Leo_Pop

Leonardo da Vinci, Vitruvius figure, kit 1:16. 2020
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
41 pieces, wood. Revell, Bünde
23 cm (h)

Leonardo da Vinci, mug. 2020
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
ceramic. Spreadshirt, Leipzig
10 x 12 cm (h x d)

Fritz, Jean, and Hudson Talbott. 2001. *Leonardo's Horse*. New York: G.P. Putnam's Sons Books for Young Readers
Private ownership, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
29.5 x 21.5 x 1.2 x cm (h x w x d)

Spigo, Lavender handcream. 2020
Max Planck Institute for the History of Science, Berlin.
Photo: Yvonne Rischke, Kiwi-Foto
Da Vinci Nature, Florence
5.5 x 4.7 x 4.7 cm (h x w x d)

Leonardo da Vinci, doll. 2011
Private ownership, Berlin
Photo: Sabine Hoffmann
From the series "Little Thinkers". Polyester and HDPE pellets. The Unemployed Philosophers Guild, Brooklyn NY. Made in China
34 cm (h)

Leonardo da Vinci, Leben und Leben lassen, Board game. 2002
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
Götz Vincentz. DA VINCI-Spiele Verlag, Hamburg
34 x 23 x 5 cm (h x w x d)

Walt Disney. 1976. *Goofy als Leonardo da Vinci. Das große Goofy-Album*. Vol. 1. Berlin: Egmont Ehapa
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
ca. 24.6 x 17.6 cm (h x w)

Leonardo da Vinci, figurine. 2020
Max Planck Institute for the History of Science, Berlin
Photo: Yvonne Rischke, Kiwi-Foto
POP! Artists. Funko, Everett, WA
9.5 x 6.4 x 6.4 cm (h x w x d)

Essays

All Images for Essays
Images_Essays

Table of Contents of Essays

Which Leonardo Are We Dealing With?

Matteo Valleriani and Jürgen Renn

Truth only became a daughter of time
Leonardo da Vinci
Paris MS M, fol. 58v

Historical research can be an adventure, an expedition into unexplored territories that may uncover surprising facts, as well as unexpected twists and turns. Yet these unknown territories actually belong to our own past: *de te fabula narratur*—the story is told of you—always! History writing may be a thrilling occupation, but it can also be most useful, serving the memory of mankind and thus contributing to humanity's awareness of itself—a knowledge that we need to situate ourselves, to understand how we got here, and where we actually are.

Reconstructing the past and communicating historical arguments always bring together two different sources of knowledge: knowledge of our past and knowledge coming from our current situation. Together, they shape our perspective on the world, including that of the past. In this sense, history may serve as a mirror producing an image of ourselves in a very special light for which we know of few other sources. Typically, we may learn, under this light, about our own otherness, which encourages us to question much of what we would otherwise simply take for granted, accepting it as self-evident and devoid of alternatives. Only in the light of history may we become aware of the situatedness our own perspective on the world and perhaps of possibilities to revise it. History is never just about facts. It is also about possibilities, often missed opportunities, but also always chances that we may still take up in the future.

Therefore what we can say today about Leonardo da Vinci does not only concern him but also, and perhaps even more, ourselves. But there is, of course, also the danger that our current point of view too rigidly dominates our image of the past, spoiling the opportunity to learn from the historical analysis about how to refocus or adapt this perspective to the concrete objects of the analysis. Thus, in an age in which "innovation" dominates the rhythm of modern societies, Leonardo came to be seen, almost exclusively, as *the* prototypical innovator, engineer, and inventor, whether in machine construction or in painting. In particular, he became the precursor *par excellence* of modern science and engineering. That he left so many things incomplete is seen from this hindsight perspective just as a confirmation of this precursor role: others had to continue and complete what he prematurely began and had to leave unfinished.

What is lost in this "linear perspective" on progress is precisely the element of otherness that distinguishes his intellectual cosmos from that of our current world. Given the dilemmas into which the "progress" of the technological mastery and economic exploitation of nature has meanwhile led us, such as ecological disasters, biodiversity loss, and climate change, the "other" Leonardo, who envisioned major catastrophes on the scale of the great Deluge (61 □) as well as harmony between humanity and nature (40 □) that can be experienced in every detail, is emerging as a new reference point.

There is also the “other” Leonardo for which work in progress was more important than a finished work, who quite consciously not only practiced “concept art” but also “concept science,” insisting on their inseparability. And there is the Leonardo capable of thinking in terms of opposites, striving to find a balance without sacrificing them to simplistic clarity. We also see Leonardo working at the threshold of a media revolution, from the manuscript to the book world, a transition comparable to our current transition from the Gutenberg Era (13 □) into the digital world. And finally, we recognize yet “another” Leonardo who is not the lonely genius, standing apart from the intellectual world of his time, who prematurely anticipated many of the great inventions that later came to shape our technological world. This “other” Leonardo stands squarely in the middle of the intellectual world of his time, and this is nowhere as visible as in the books that surrounded him.

Books—whether printed or in manuscript—are vehicles of knowledge circulation. They represent the shared knowledge available in a given historical situation. An individual library is a window into this world of shared knowledge. It opens up a personal perspective that may give this world a new order and sense, which yet remain firmly rooted in the common possession. In the case of Leonardo, the seemingly incommensurable genius, such an interplay between shared knowledge and individual perspective has its special charm because it allows us to relate his flashes of inspiration to a commonly shared horizon—if we succeed in reconstructing the sources of his knowledge. We should not forget that the very possibility of composing an individual library in this time, especially considering the size and scope of Leonardo’s collection, depended not so much on his genius but on another shared precondition—the still recent invention of the printing press and the new knowledge economy to which it gave rise (5 □). Leonardo’s genius could unfold in the way it did only on the basis of the shared knowledge and its dramatically enhanced circulation that this economy made possible (CR Vecce).

Historians, and especially historians of science, love to reconstruct ancient libraries precisely because they constitute a representation of the shared knowledge of a given period. By reconstructing the catalogues of the ancient library of Alexandria, for example, historians have attempted to recreate the shared knowledge of the entire Hellenistic epoch. In our case, we are dealing with the then still rare case of a private library, not of a prince or a bishop, but of an “ordinary” person, of an artist and engineer-scientist. What do his books tell us about Leonardo’s intellectual profile and what can they tell us about the newly available possibilities of the time to form such an intellectual profile?

Leonardo left lists of books on five different folios (2 □; 3 □; 4 □). On one of them, we actually find three lists of books, so that we are dealing with a total of seven lists. It is reasonable to assume that such lists were produced to record his own books. There are indeed many hints that make this assumption plausible, such as the mention of these books in other notes by Leonardo, scattered among the more than 4,000 manuscript pages that he left and which are still preserved today. In one case (*Codex Madrid II*, fol. 2v), Leonardo’s list is entitled “Note on the books I’m leaving locked up in the chest,” which suggests that the other lists also record his books. This interpretation seems to be a reasonable generalization, confirmed by the fact that some of the listed books reoccur in different lists. The hypothesis that the lists indicate books of Leonardo’s growing personal library also matches our own habits of dealing with books. But we cannot rule out the possibility that at least some of the lists were made for other purposes, for instance, to record a list of books he wished to acquire or books owned by somebody else.

Reconstructing Leonardo's library has been over a century in the making. Scholars currently studying his extant documents, who are trying to identify the reference points of his intellectual cosmos, stand on the shoulders of giants and have been working off of over 100 years' worth of research. The first reconstruction of Leonardo's library dates back to 1873 and was realized by the bibliographer Girolamo d'Adda. A complete record of all the books mentioned in all of Leonardo's codices was made in the 1970s by Nando de Toni. Multiple reconstructions of Leonardo's libraries were published in the last 50 years, but on the occasion of the 500th anniversary of Leonardo's death, Carlo Vecce published his new and comprehensive results. His findings became the starting point of a series of library reconstructions, with "Leonardo's Berlin Library" being the most recent instance. Before that, Vecce's work was used for the preparation of two other exhibitions displaying Leonardo's library: one in Florence (June 6—September 22, 2019), also shown in Rome (October 4, 2019—January 12, 2020), and one inStanford (May 2—October 13, 2019). Although based on the same research results, these three libraries of Leonardo are by no means identical. Remarkably, because of their differences, they show us different facets of Leonardo's intellectual profile—or shall we rather say: they show us a different Leonardo?

Fig. 1: Nina Bätzing, Esther Chen, and Marvin Müller (together with Falk Eisermann and Matteo Valleriani) at the Staatsbibliothek zu Berlin while controlling the selected incunabula and manuscripts and acquiring electronic copies of representative pages and folios for each of them. Berlin, August 19, 2020. Photo: M. Valleriani.

The library thus reveals itself as a picture puzzle, a reflection of the mobility of knowledge and of the changes it undergoes in the process. The diversity of Leonardo's libraries is caused by several factors. One reason is due to the ambiguities of the philological interpretation of his notes, in which he often just jotted down a misspelled name or a generic short title, another is rooted in practical concerns. As for the latter, any reconstruction that moves from paper into an exhibition requires a materialization of the results of the historical analysis. Not only must Leonardo's books be identified but extant exemplars of these books in today's libraries and collections must also be found. This effort is further constrained by the availability of such books in a given place. Only a few institutions hold collections rich enough to supply a complete reenactment of Leonardo's library. The choice of books available in a given place, including exemplars of varying editions and provenances, thus unavoidably shapes a particular instantiation of Leonardo's library. These circumstances are not to be considered a deplorable disadvantage but actually constitute a tribute to the local collections and their striking capability to furnish a 15th-century library! In our case, we have profited from the riches of the incunabula collection of the Staatsbibliothek zu Berlin that is at the core of Leonardo's Berlin Library (Fig. 1).

Fig. 1: Nina Bätzing, Esther Chen, and Marvin Müller (together with Falk Eisermann and Matteo Valleriani) at the Staatsbibliothek zu Berlin while controlling the selected incunabula

and manuscripts and acquiring electronic copies of representative pages and folios for each of them. Berlin, August 19, 2020. Photo: M. Valleriani.

Image:
01_Valleriani_Renn_01

But let us come back to the first reason for the ambiguity of any reconstruction of Leonardo's library, the philological problems. The laboriousness of interpretative work depends on the form and substance of the actual historical sources at hand. In the case of Leonardo's library, there are multiple challenges posed by his occasionally cryptic notes. This imposes further constraints on a transformation of research results into a physical space. Some examples from Leonardo's own notes may serve to illustrate the case in point.

On page 2r of the *Codex Trivulzianus*, at some point probably between 1487 and 1490, Leonardo entered the word "*d'abacho*" in a short list of books (2 □). While the meaning of the word "abacho" is clear, referring to a counting frame used in Renaissance-era Italian trade schools, the identification of a specific work "on the abacus" is substantially impossible on the basis just of this note. What is clear is that Leonardo refers to an abacus treatise, most probably a schoolbook used in the context of the curriculum of an abacus school. In these schools, young students learned arithmetic, mostly in order to prepare themselves for merchant activities, in short: to learn math for business (16 □; 19 □; 20 □). Such schools were widely spread in Leonardo's time and the books they used circulated even more widely. The "Liber abbaci" by Leonardo Pisano (1170–1240), also known as Fibonacci, is one of the most famous instances. While, in this case, no clear information about the work and its edition can be extracted from Leonardo's booklist, we nevertheless gain a clear perception that, at some point, Leonardo must have studied the mathematical subjects covered by this abacus tradition.

In the same booklist, we also find the note "*plinio*." In this case we are confronted with two plausible alternatives: Pliny the Elder—or Pliny the Younger. We know that one of the most widely read works of the Renaissance and the early modern period was Pliny the Elder's *Historia naturalis* (52 □). We are thus compelled to choose this work as the more likely alternative, without, however, being able to identify a specific edition because of the large number of printings and manuscripts circulating in Leonardo's time. But we also encounter another challenge: For a treatise on the abacus it is reasonably clear what subject matters it addresses and what Leonardo could have learned from it, whatever specific text was meant. For a very substantial encyclopedic work, in which Pliny intended to "capture" the entire knowledge on nature of his time, it remains, in contrast, impossible to draw inferences about the knowledge that Leonardo may have gained from it. We cannot know whether only some subjects or the entire work were of interest to him. Other entries in Leonardo's lists pose even more serious problems because his scant notes do neither allow the identification of a particular work nor the knowledge that Leonardo may have acquired from it. In all cases, the identification of the specific edition that Leonardo possessed is just impossible because his notes are of a private nature and hence do not report bibliographic data in the technical sense of the word, as if they belonged to a library catalogue.

In the face of such ambiguities, an exhibition poses a particular challenge. In a scholarly publication, in particular one written by a cautious historian, one has the possibility of presenting alternative reconstructions, adding footnotes, references, and commentaries that help the reader to weigh the arguments for and against the different options. Over the course of time, a consensus may form among the community of experts that remains stable at least until some new evidence is found. The case of an exhibition is different in two respects. First, since research results are to be materialized in a physical space, a definitive choice has to be made about which object to exhibit, even if its label may then relativize that choice. Second, the consensus about what to exhibit is not limited to a community of historical experts but has to be reached among the wider group of curators, librarians, designers, publication managers, and coordinators. In the times of the COVID-19 pandemic, this consensus had to be found during long, sometimes entertaining and sometimes exhausting video-meetings (Fig. 2).

Fig. 2: Discussion about the best way of presenting the results of the interpretation of Leonardo's notes. From top left clockwise: Elizabeth Hughes, Matteo Valleriani, Antonio Becchi, Sabine Hoffmann, Jürgen Renn, Serge von Arx. Berlin–London–Oslo, November 18, 2020

Fig. 2. Discussion about the best way of presenting the results of the interpretation of Leonardo's notes. From top left clockwise: Elizabeth Hughes, Matteo Valleriani, Antonio Becchi, Sabine Hoffmann, Jürgen Renn, Serge von Arx. Berlin - London - Oslo, November 18, 2020

Image:
01_Valleriani_Renn_02

These discussions gave rise to some new insights and pathways of investigation. But more importantly, they generated a particular profile of Leonardo himself. To better understand how that profile emerged from our efforts and how Leonardo's image was shaped by us, let us now move back to the end of the 15th century.

In the list of books on fol. 559r of the *Codex Atlanticus* (ca. 1495) (3 □) we find the short entry "spera." Between eight and nine years later, on fol. 3r of *Codex Madrid II*, Leonardo wrote a similar note: "spera mundi" (4 □). For a modern reader these notes may appear to be cryptic, but for anybody living in the early modern period who enjoyed some education it was crystal clear to what they refer: an introductory text to geocentric cosmology known under the title *De sphaera*, in its correct Latin spelling. The title is actually of a generic kind, covering an entire group of textbooks used at the end of the 15th century in universities for introductory classes on astronomy during the first year of studies in the liberal arts faculties.

The most widely spread treatise of this group was a 13th-century compilation by Johannes de Sacrobosco, originally written for the students of the University of Paris. In the early modern period, *sphaera*, or even just the name of the author, Sacrobosco, came to denote not only this specific treatise but an entire knowledge system. A succinct description and explanation of the geocentric cosmos and of the movements of the celestial bodies are at the center of this knowledge system. In the course of its circulation over centuries, ever more knowledge was assembled around this core. The introductory treatise was thus supplemented by other texts whose subjects could expatiate from astrological medicine to mathematical models for calculating the positions of the planets. In this way, the original system of knowledge evolved over time, from the late Middle Ages to the end of the early modern period, when it was substituted by the Copernican worldview.

As a matter of fact, the wide dissemination of the *Sphaera* knowledge contributed to the importance that the "Copernican revolution" eventually gained beyond the realm of technical astronomy, in particular because the *Sphaera* integrated astronomical, geographical, and other knowledge into a veritable worldview. This worldview included many aspects that were of interest not only to specialists. Navigational and calendric knowledge, for example, was of increasing relevance in an ever more mobile and connected world. Thus, paradoxically, the popularity of the geocentric worldview propagated by the *Sphaera* helped to create the conditions for overturning this worldview in favor of a new cosmology that concerned not only astronomers but the learned public more generally, including the religious controversies to which it gave rise. This powerful role of the *Sphaera* was not least due to the fluidity of the system of knowledge for which it stands.

One way to expand the *Sphaera* knowledge was to copy the basic treatise together with other texts in a manuscript or, in the case of printed texts, to collect several texts in one volume. Another, even more common approach was to comment on the original text and, in doing so, to criticize, correct, and enrich it. There were different kinds of commentary: It could slavishly follow the original text, split into paragraphs to which then the commentary, segmented as well, directly referred. Alternatively, a commentary could offer a paraphrase, occasionally changing the meaning of the original text or inserting additional content. The original text of reference could thus even virtually disappear in a new edition, being reduced to little more than a specialized chapter or an appendix. This process of revision and transformation of the *Sphaera* knowledge was, of course, much accelerated by the new technology of printing, and Leonardo found himself squarely in the middle of this transitory period.

The popularity and diffusion of the *Sphaera* offers a wide range of possibilities for identifying Leonardo's notes with specific texts. The diversity of contents in the different compilations and editions makes it even difficult to circumscribe the knowledge that he acquired from the books to which he referred. This knowledge can only be identified with a certain degree of plausibility if we assume that he referred to the core text describing the *machina mundi* and its movements.

Leonardo might have possessed a handwritten copy of Sacrobosco's text, and this would make it impossible to determine which one, because of the almost innumerable handwritten copies that had come into circulation since the 13th century. But even if we only consider the printed editions, there were already 25 by 1495. A later note (4 □) in his booklist indicates that he may have purchased another book on the subject between 1495 and 1503 or 1504, meaning a further 17 editions must be added to the spectrum of possibilities. Of these 42 editions, 13 were printed in Venice, 11 in Leipzig, and 8 in Paris, to mention only the three major places of production for this selection.

Between 1469 and 1506, Leonardo lived in Florence, then in Milan, in Mantua, and again in Florence (Life and Legacy B □; Life and Legacy C □; Life and Legacy D □; Life and Legacy E □). Therefore, the most plausible, but not certain, inference is that he would have possessed a copy of an edition printed in Venice. Such plausibility is increased by the fact that Venice was one of the major centers of book production during the entire early modern period and the first one to gain a transregional, European continental market (5 □).

Carlo Vecce, in his comprehensive reconstruction of Leonardo's library, as well as Carmen Bambach, in her monumental *Leonardo da Vinci Rediscovered* (2019), associate Leonardo's note with a little-known treatise by Gregorio Dati (1362–1435), posthumously printed in Venice around 1475 by Gabriele di Pietro. The treatise, written in Italian, had been circulating since the first quarter of the 15th century. One hundred and forty-eight manuscripts containing this text are preserved today. Vecce and Bambach might have followed the suggestion made for the first time by Girolamo d'Adda in his first 1873 reconstruction of Leonardo's library, and then recently by another historian, Romain Descendre. In his 2010 book, *La biblioteca di Leonardo* (Atlante della letteratura Italiana, Vol. 1), Descendre associates Leonardo's note with Dati's work and also with a printed edition of the more standard and more widely circulating *Tractatus de sphaera* by Sacrobosco (Ferrara 1472). Descendre probably favored this option because this work was printed for the first time in 1472 in Ferrara, though another edition was also printed in the same year in Venice.

These are, however, not the only options compatible with the available knowledge on Leonardo's library. Another possibility is a 1490 edition, the *Sphaerae mundi compendium foeliciter inchoat*, printed in Venice by the internationally active printer and publisher Ottaviano Scoto. This edition has the added bonus that a copy is owned by the library of the Max Planck Institute for the History of Science (92 □).

Despite the impossibility of knowing with certainty which edition Leonardo possessed, we limit our options to Dati's treatise and to the Venetian print of Scoto. Both of them are very plausible choices. Dati's text was also printed in Venice, and was published in Italian, surely a convenient choice for Leonardo given his well-known struggle with the Latin language. The other text was issued by Scoto who commanded a capillary distribution network, especially in northern Italy, where Leonardo also lived. Also, Scoto was producing substantial print-runs, and his books were certainly cheaper. Now, as explained in the beginning of this essay, the features of the phantom picture of Leonardo that any reconstruction generates depends on such choices. So, which Leonardo are we dealing with?

To answer this question, we need to open both books. Dati's work is a poem written in *ottava rima* (a stanza of eight lines with the rhyme-scheme a-b-a-b-a-b-c-c), composed of four books (which we would now rather define as chapters). If compared with the original medieval compilation of Sacrobosco, this work is a commented paraphrase that offers an introduction not only to geocentric cosmology but also to geography and astrology, while showing a strong religious motivation. It is a beautiful piece that brings together knowledge from the 14th century, when cosmology was more often related to astrology and medicine, with a most recent trend of the early modern period—the growing interest in geography. The book also contains Portolan-like maps, produced for navigation purposes. We are thus reminded of the aforementioned theme of the increased mobility of this period (104 □; 105 □; 106 □), enhancing the significance of texts like the *Sphaera* that provided useful knowledge for travelers whether by land or by sea. Dati was indeed a very successful silk merchant with wide-ranging connections. Let us take a closer look at one of his stanzas, in our translation, where he defines the "firmament" (Fig. 3).

Fig. 3. Gregorio Dati [ca. 1475]. *La sfera* [Venice: Gabriele di Pietro]. Library of Congress, Rare Book and Special Collections Division

Image:
01_Valleriani_Renn_03


POTENTIA.SAPIENTIA.AMORE.
N el alto imperio ciel con firma essentia
Comanda e uolge e regge il firmamento
Loqual ci monstra la tua gran potentia
Per lo suo smesurato abraciamento
Cognoscesti infinita sapientia
A riguardare il grande adornamento
Per noi creasti a ciel tanto splendore
E qui sintende linfinito amore.
GRANDE.VELOCE. BELLO.
L a sua grandezza passa ogni intellecto
La sua uelocita uia piu transcende
Quanta bellezza e di quanto dilecto
Si uede in epsoe chi col cor attende
Veramente a cosi alto rispecto
Lalma gentil damor tutta saccende
Dexiando poter salire a quelle
Nobile creature e chiare stelle.
TRAMONTANA.
V eggio la stella in su chel polo gira
Cum quelle septe e due che uano intorno
Le qual per neccessita assai si mira
Da nauecanti quando manca il giorno
Chi la cercasse e trouar la desira
Locchio suo guardi la bocca dun corno
Chi piu sapresso ad uederle supine
Piu fredo sente & iacciato confine.
LALTRA TRAMONTANA.
D a la opposita parte e laltro polo
Simele a quello e fredo di natura
Che non si puo mirare dal nostro solo
Perche tra noi e quello e grande arsura
La qual e sempre sotto un cerchio solo
Che fa la nocte el di de egual mesura
Tra questa calda e le due frede zone
Sono i luochi habitanti et le persone.

Fig. 3. Gregorio Dati [ca. 1475]. *La sfera* [Venice: Gabriele di Pietro]. Library of Congress, Rare Book and Special Collections Division

The stanza is entitled: *Power, Knowledge, Love*

> In the high reign of the sky with firm essence
> [he] rules, moves around and holds the firmament,
> which shows us your great power.
> For its boundless embracing
> you possessed an infinite knowledge.
> In order to look at the great ornament,
> you created for us such a splendor in the sky;
> and here we understand the infinite love.

The firmament is moved around by the *primum mobile*, here identified with God ("*firm essence*"), and this transmits the circular movement ("*moves around*") to the firmament, the sphere of the stars, which is shown in the accompanying illustration. All of Dati's work is enriched by a significant number of illustrations. Those of the printed copy were most probably added by hand after printing and colored either in the workshop or by the reader, as was still common in this phase of the evolution of the printed book as a product.

Although it shares the same nucleus of knowledge, Scoto's 1490 edition introduces us to a somewhat different intellectual world, closer to current astronomical concerns and the pertinent technicalities (92 □). In fact, the trend toward a mathematization of astronomy grew in relevance over time within and outside the *Sphaera* tradition, but mostly only after Leonardo's lifetime. Scoto's work is not a commentary but rather a compilation of three texts, all of them subsumable under the label sphaera.

The first text is essentially the original treatise of Sacrobosco. But it is not exactly a re-print of its original form. Rather, Scoto probably used a 14th-century manuscript of the *Sphaera*. In such manuscripts, Sacrobosco's text was often introduced by a short anonymous treatise on geometry. Sacrobosco's original design of the book started with a geometric definition of the sphere in order then to show its correspondence with the real shape of the cosmos. Over time and probably for pedagogic reasons, teachers and commentators thought that before weighing down the students with such a definition, they would profit from an easy-going introduction into geometry starting from definitions of line, point, and angle and stopping at the definition of a circle. Scoto “packed” this introduction into the original text and sold the whole as a *Tractatus de sphaera*.

Sacrobosco’s text is divided into four books (or chapters) as well. It is a straight and dry description of the parts constituting the cosmos and all their movements. In the third book, it deals with subjects striking the modern reader as somewhat out of place for an introduction into astronomy. Some of them are indirectly related to medicine. For instance, Sacrobosco describes the climate zones on the temperate part of the planet; these notions were indispensable to contemporary physicians, conceiving individual dietetic plans based on the relation between the complexion of the patient and the place where he, rarely she, lived. The fourth book—considered to be the most challenging one ever since its publication—represents a bridge from qualitative cosmology to mathematical astronomy, as it tries to describe, with little mathematical ambition, the motion of the sun and the moon and subsequently to explain the phenomena of solar and lunar eclipses.

It is probably because of this last, unclear and incomplete part of Sacrobosco’s treatise that university lecturers exerted pressure on publishers like Scoto to enrich the volume with other explanatory and more up-to-date texts. In fact, both the second and the third text of Scoto’s edition go back to the work of two of the most famous 15th-century astronomers, Georg von Peuerbach and his pupil Johannes Regiomontanus. They had redesigned the method for calculating the positions of the planets in the framework of early modern geocentric astronomy.

The third text is Peuerbach’s *Theorica nova planetarum*, written in 1454 and posthumously published in 1472 by Regiomontanus. Peuerbach had reacted to the older “theory of the planets”—usually attributed to the late medieval astronomer Gerard of Cremona—a text that meanwhile was considered as deficient. The second text, the text in-between, is Regiomontanus’ *Discussion against Gerard of Cremona’s ravings [sic!] on the theory of the planets*. In spite of such a polemical title, this work is a technically demanding demonstration of Gerard’s mistakes. It served as a prefatory work to Peuerbach’s *Theorica*. It is unclear when this text was written—but certainly not before 1464. Regiomontanus was perceived then and now as the most brilliant mathematical astronomer of the century. His most famous work is the *Epytome*, the so-called abridgments of Ptolemy’s *Almagest*. There, he suggested alternative models for the orbits of Mercury and Venus, which influenced Copernicus’ work. The *Epytome* were published in 1496, six years after Scoto’s edition.

Comparing our two candidates for Leonardo’s library, Dati and Scoto, we find in both remarkable blends of older and more recent views. The basics of geocentric cosmology constitutes their common core. For instance, the notion of the firmament, which we have encountered previously in Dati’s text, we also find in Soto, in the part that contains Sacrobosco’s orginal text. Sacrobosco introduces the firmament while describing the cosmos at the very beginning of his work. In accordance with the tradition going back to Aristotle, he defines the *primum mobile* as the motor that transmits motion to the firmament. In Lynn Thorndike’s 1949 translation:

> The sphere is divided in two ways, by substance and by accident. By substance it is divided into the ninth sphere, which is called the “first moved” or the *primum mobile*; and the sphere of the fixed stars which is named the “firmament;" and the seven spheres of the seven planets, of which some are larger, some smaller, according as they the more approach, or recede from, the firmament.

In Dati we still find the vision of scholastic natural philosophy according to which astronomy, astrology, medicine, and even music constitute a harmonious and morally laden system of knowledge anchored in theology and a holistic cosmology. While Sacrobosco does not leave room for theological disquisitions, they do enter Dati's text, as we have seen. Dati's comprehensive vision was nevertheless also able to absorb and embed new impulses such as those created by the growing interest in geography.

In Scoto's edition, we also find traditional elements such as Sacrobosco's text, which was written at least 140 years before Dati's. But otherwise, it represents a "modernized" version of the *Sphaera*. It was compiled as an introductory textbook for contemporary students eager to learn geometry, astronomy, and cosmology "from scratch," and it also included a critical text on the best-known theory of the motion of the planets, as well as a proposal for its renewal. Scoto's edition represents a tendency growing out of medieval scholasticism toward a higher degree of specialization in astronomy, rejecting the holistic vision at the center of Dati's work. From Scoto's perspective, this was hardly more than science for poets written by an amateur.

Both Dati's and Scoto's texts incorporate late medieval traditions as well as contemporary, early modern developments. And yet they appear to diverge from each other to the extent—as we can see now—that one tradition (Scoto's) one day, much later, would consider the other one (Dati's) as non-scientific, mainly because of its inclusion of astrological concerns.

Exhibiting one or the other of these two texts in Leonardo's Berlin Library may thus appear to have dramatic consequences on the image of Leonardo that is being projected. In dependence on which book is associated with his library (and his personality), we either see him as a brilliant artist and visionary artisan who was also a gullible scientific layman, content with a popular version of Christian cosmology, or we can admire him as a keen adept of an innovative science, unstoppable on its way toward a mathematical and quantitative conception of nature. These are, of course, exaggerations to the point of becoming caricatures, also because the choice of a book is not necessarily the signature of a personality.

But the ambivalence of the reconstruction of Leonardo's library reveals itself, on closer inspection, as an ambivalence of the contemporary intellectual constellation in which Leonardo found himself in the last years of the 15th century. The advent of printing technology and especially of the technique of movable letters had lowered the threshold of access to knowledge in a historically unprecedented way. For a long time, however, what was distributed was mostly medieval knowledge. As the historian Michael T. Clanchy put it in 1983: "the immediate consequence of printing was to make medieval books more widely available." The encompassing knowledge system constituted by the combination of cosmology, astrology and medicine, enriched by stone studies (*lapidaria*) and alchemy, experienced an impetuous revival, and was recontextualized by the emergence of a new Platonism, inspired, in particular, by the works of Marsilio Ficino and Pico della Mirandola.

Their idea of man as a "receptacle of the world" and as a "creature of indeterminate image," as everything and nothing at the same time, fits well with Leonardo's longing for an integral observation of nature, always competing with his personal fantasy and creativity. From this perspective, the two *Sphaera* works, one projecting the image of a harmonious cosmos with man at its center, the other striving more ambitiously for a mathematical understanding of at least some aspects of this cosmos, are not mutually exclusive in Leonardo's world. It was his personal activity, his always being in motion, painting and studying nature at the same time, that preserved the unity of this world. For him, as well as for his Renaissance contemporaries, the story as a whole was as important as the attention to the detail, accessible only through indefatigable observation and experimentation. Both dimensions belong to an emphatic notion of experience, rooted in and encouraging novel ways of exploring the world.

One of these ways was, of course, mobility—in terms of both the circulation of knowledge and the travelling of people experiencing an expanding world (99 □; 100 □; 101 □; 102 □; 103 □). The new mobility was comparable only to the one practiced in antiquity in the Mediterranean region. It was the hallmark of a new mercantile culture that had emerged in Europe since the 13th century and that motivated adventurous traveling all over the continent, as well as beyond its frontiers toward the south and the east. In Leonardo's time, Marco Polo's travel to Catai still exerted a more profound influence on the public imagination than the news that Christopher Columbus had found a westward route to India, as the idea that there might be another continent in-between was still hard to fathom.

The mercantile culture contributed significantly to the circulation of goods and knowledge. It also spurred the colonial expansion of the European powers with devastating consequences for the indigenous populations of other continents. It enhanced the significance of knowledge for practical purposes, for instance, geographical, astronomical, nautical, and cartographical knowledge for mastering the challenges of traveling, as well as mathematical knowledge useful for a new financial system. All in all, mercantile activities significantly shaped what historians now call the "practical turn" of science in the early modern period.

Another significant push in the same direction came, in Leonardo's time, from technological developments in the military realm. The diffusion of a new heavy but easily transportable artillery in the course of the Italian wars gave rise to a new culture of architecture that quickly spread across Europe. It was called the "new geometrical way of fortifying" and gave a most decisive impulse to the application of geometrical and mathematical methods to technology, architecture, and urbanization. A new mechanics was instigated by challenging objects of technology, such as cannons and the trajectories of their projectiles, but also by the study of practical mechanical devices such as balances or the pendulum (CR Galluzzi; CR Renn/Schemmel). By the time of Galileo Galilei, preclassical mechanics had emerged as a highly conflictual intellectual field of encounter between these challenging new experiences and the rich legacy of theoretical knowledge of the ancient world, of the Islamicate civilizations, and medieval scholastics. While this development was still in its infancy during Leonardo's lifetime, all of these elements can already be found in his manuscripts.

This reading, however, should not tempt us to draw anachronistic conclusions about Leonardo the premature pioneer, *en route* along a predetermined pathway to modernity. As we have seen in the case of the *Sphaera* tradition, neither Dati's nor Scoto's works were, by themselves, apt to fully capture Leonardo's intellectual profile. Just as the multifaceted *Sphaera* tradition of the 15th century harbored a richer legacy than what is incorporated in either of these works, a legacy that could in fact engender quite different intellectual pathways, Leonardo himself cannot so easily be framed in terms of familiar categories. Perhaps he is best described by one of the fables in Francis Bacon's *De sapientia veterum* from 1609, dealing with the always mutable Proteus, representing what is knowable in nature. Leonardo reminds us of the hunter running after Proteus who never succeeded in fully extracting all of nature's secrets. Breathless in his endeavor, he did not even find the time and the means to make at least some of his ideas public, for instance, by publishing a book.

Leonardo instead compiled manuscripts—while we fill websites. The two media are more similar to each other than meets the eye. Both refuse the fixity of print. Both are constantly updated, annotated, excerpted, and connected by links to other subjects. They are media apt to open-ended explorations and investigations. Perhaps we see Leonardo as the hunter of Proteus precisely because we are now such hunters ourselves.

Confronted with fundamental challenges of planetary dimension, in the age of the Anthropocene, when rapid changes of the Earth system affect our lives profoundly, we now perceive the need for another paradigm shift. We no longer see ourselves as observers of a nature that exists separately from us, nor as her children to which she kindly provides her seemingly endless resources. Nature has largely become our own product, the result of the global application of science and technology in the context of an extractive economy. The rapidly changing Earth system has now become the new Proteus whom we are hunting in order to change the course of history for a world in which we can survive. We no longer consider Leonardo primarily as a visionary genius beyond human measure, but rather as one of us, as an ally from whom we may learn about the tireless passion of investigating connections between the large and the small, the dynamics of change at every level, the interdependencies of science and culture, and the courage to formulate daring ideas and put them into practice, however impossible this may seem.

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Leonardo’s Library: The Books and the Cosmos

Carlo Vecce

There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.
William Shakespeare (Hamlet, 1, 5, 167–168)

The great book of nature (written in “mathematical” words, as Galileo would have said) is infinitely more expansive than all books written by humans. From the beginnings of his adventures in the realm of knowledge, Leonardo da Vinci was completely aware that he would examine this book in all possible directions throughout his life. Every intellectual conquest, every new discovery of a physical or mathematical law, every hypothesis explaining how the machine of the world works implies the awareness that these are only preliminary goals, that there is no final goal, and that the “last horizon” (as Giacomo Leopardi would one day describe it in his poem *L’infinito*) is simply deferred a little.

It is more difficult to read and understand the book of nature than a book of poetry (and Leonardo knew very well that of all of the books written by humans, books of poetry may be the most difficult from a rhetorical and stylistic standpoint, requiring, like Dante’s Divine Comedy (21 □), commentary and marginal notes): “How much more difficult it is to understand the works of nature than the book of a poet” (*Codex Madrid II*, fol. 87v). Leonardo often contrasted the boundaries ascribed to the knowledge handed down through the tradition of the *auctores* with the value of *sperientia*, direct experience of phenomena and reality; but even then, he had to recognize that human *sperientia* could never lay claim to the “fathomless reasons” of nature: “Nature is full of fathomless reasons that are never experienced.” (*Paris MS I*, fol. 18r). This previous sentence is actually from *Paris MS I*, which can be dated to 1497–1499. It is partially dedicated to the problem of the proportionality of motion in relation to resistance, against the hypotheses of the so-called “proportion” authors (Aristotle, Albertus Magnus, Albert of Saxony):

> You investigators therefore should not trust yourselves to the authors who by employing only their imaginations have wished to make themselves interpreters between nature and man, but only to those who have exercised their intellects not with the signs of nature but with the results of their experiments. (*Paris MS I*, fol. 102r)

Leonardo educated himself outside of the mainstream of humanistic culture that prevailed in the schools and universities of the Renaissance; his culture was the practical culture of the workshops of artists, engineers, and craftsmen, in which *sperientia*, seeing and doing, prevailed . He could not speak Latin and had had an erratic and largely autodidactic education, but he was open to experimentation and research, even beyond the established boundaries of the classical and medieval scholarly and philosophical tradition. The idea that the books handed down by tradition contained all human wisdom and were sufficient for understanding the world completely was gradually cast in doubt toward the end of the Middle Ages by important discoveries (often from the Arab world and the East) in the areas of optics, astronomy, mathematics, medicine, mechanics, and metallurgy; and soon the expansion of trade routes and waterways shattered the geographical boundaries of antiquity and led to the discovery of new countries and new continents that had never before been drawn on maps or described in the books of historians or cosmographers.

Leonardo would never deny his education as a "*discepolo della sperientia*" (student of experience) (as he writes regarding the drawing of a fantasy Mazzocchio, a type of traditional headgear from the 15th and 16th century), (Fig. 1). But at a certain point in his life, he would feel the need to enter the world of written culture, the world of books. In Milan of the 1480s, just before he turned 30, Leonardo decided to systematically deepen the research he had begun in the preceding years, developing it in an organic form by means of writing and even as a treatise. In the manuscripts dating from these years (which are also the first notebooks created by Leonardo: *Paris MS B* and *Codex Trivulzianus* (108 □)) we can recognize intensive consultation of certain books, with the goal of refining the young artist-engineer's linguistic resources (vocabulary, style, rhetorical devices). Leonardo was aware of his own limitations and made an effort to overcome them, but at the same time he replied proudly to those who might have accused him of being a *homo sanza lettere* (someone who didn't know Latin), that instead he was a direct student of nature and of *sperientia* (experience) and not of books and *auctores* (authors, or *altori*, as he called them): "I am fully aware that the fact of my not being a lettered man may cause certain arrogant persons to think that they may with reason censure me, alleging that I am a man without letters" (*Codex Atlanticus*, fol. 327v) (37 □); and once again: "Even if I cannot draw on the authors ("*altori*") as well as they, that which I draw on is far greater and worthier, because it is experience, the mistress of their masters, that I draw upon" (*Codex Atlanticus*, fol. 323r).

Fig. 1: "Corpo nato della prospettiva di Leonardo Vinci discepolo della sperientia" (Body born from the perspective of Leonardo Vinci, a student of experience), *Codex Atlanticus*, fol. 520r. *Codex Atlanticus*, Biblioteca Ambrosiana, Milan, ca. 1478–1518, fol. 520r. Reprint: 1973–1974. Il Codice Atlantico Vol. 6. Florence: Giunti

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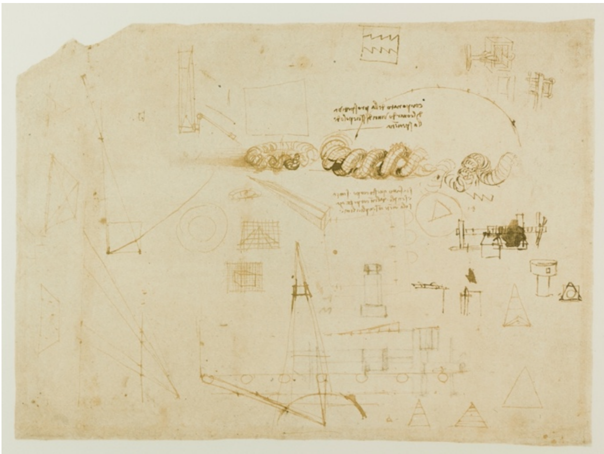

Fig. 1: "Corpo nato della prospettiva di Leonardo Vinci discepolo della sperientia" (Body born from the perspective of Leonardo Vinci, a student of experience), *Codex Atlanticus*, fol. 520r). Leonardo da Vinci. *Codex Atlanticus*, Biblioteca Ambrosiana, Milan, ca. 1478–1518, fol. 520r. Reprint: 1973–1975. Il Codice Atlantico Vol. 6. Florence: Giunti

And so Leonardo began to collect books. He bought them, borrowed them (without giving them back), leafed through them quickly (and for free) at the stands of booksellers or in the few libraries he could enter. The books gradually became a library that developed over the course of time like a living organism that reflected the life and the physical and intellectual movements of he who cultivated it. At the end of his life, this library became an impressive instrument of research and immersion that was distinguished by its openness toward many disciplines of scholarly and technological research as well as literature, which we could call "entertainment literature": nearly 200 volumes, a considerable number for someone who wasn't a *litterato*.

Unfortunately Leonardo's library is lost to us today. After his death (1519), all of his books were entrusted to a faithful student, Francesco Melzi, after whose death (1567), the library was mercilessly scattered. So far only a single book has been identified that was read by Leonardo and annotated by him: the treatise on architecture and military technology by Francesco di Giorgio Martini (now known as the Laurentian Ashburnham Manuscript *MS Ashburnham 361* (66 □). Luckily Leonardo's own manuscripts are not sparing with information about his other books. They include direct or indirect citations of authors and texts, and most importantly longer or shorter lists of books (ones he owned, used for research, or simply wanted to have). The most significant lists correspond to key moments in his life and in his artistic and intellectual development: a short list with just five titles in the *Codex Trivulzianus*, fol. 2r (2 □) a few years after Leonardo had settled in Milan and painted the *Virgin of the Rocks* (ca. 1487); a list of 40 titles from 1495, also in Milan, at the time of *The Last Supper* (*Codex Atlanticus*, fol. 559r (3 □) (Fig. 2); and the list with the most entries from Florence in 1504, containing no fewer than 116 titles at the time of *The Battle of Anghiari* (*Codex Madrid II*, fol. 2v–3r (4 □)).

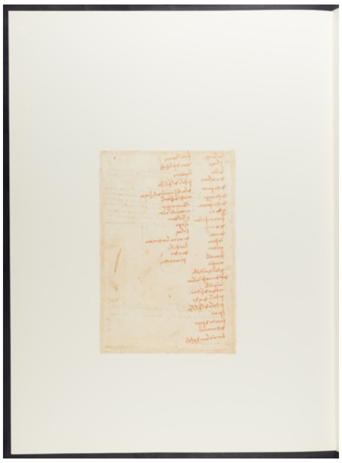

Fig. 2: A list of 40 volumes from Milan ca. 1495, at the time of *The Last Supper*. Leonardo da Vinci. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, ca. 1495, fol. 559r (3 □). Reprint: 1973–1975. Il Codice Atlantico Vol. 7. Florence: Giunti

Fig. 2: A list of 40 volumes from Milan ca. 1495, at the time of *The Last Supper*. Leonardo da Vinci. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, ca. 1495, fol. 559r (3 □). Reprint: 1973–1975. Il Codice Atlantico Vol. 7. Florence: Giunti

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The last list demonstrates a greater familiarity with the book as an object, in the form of notes on their materiality. Along with the language (Latin, vernacular, French) and literary genre, he also noted writing materials, measurement, binding, presence of illustrations, condition, and provenance. The list includes many illustrated books that were among the most significant examples of printed books between the 15th and early 16th centuries: *De re militari* by Roberto Valturio (63 □), *Fasciculus medicinae* (77 □), *Ortus sanitatis*, and *Das Narrenschiff* by Sebastian Brant (46 □). In some cases, the illustration was limited to a decorative function (the frontispiece, a portrait of the author, a holy image), but often the image was an integral component of the book's communication strategy. That is no coincidence. When building his library, Leonardo continued to value the role of images as he had observed it as a young man in the tradition of manuscripts and handbooks by engineers and artists: a "claim to the innovative and popularizing function of images" that represented a true revolution vis-à-vis classical antiquity (particularly for works that were preserved without images, such as the treatise of Vitruvius), as well as for humanistic culture, which assumed the superiority of verbal language.

Leonardo's library hardly differed from the private libraries of his contemporaries, though they belonged to a higher cultural class of scholars and humanists: scholars of physics and the natural sciences, mathematicians, physicians, and philosophers. His strategies for building his library reveal frequent contact with other readers and other libraries: exchanging and borrowing books, hasty consultations with friends or at booksellers' stands, suggestions or simply information about books he had not seen before. After spending his childhood in the Florentine workshops where the most beautiful manuscripts of the Renaissance were copied and ornamented with miniatures on the orders of princes and rulers, Leonardo was granted access to some of these magnificent lordly libraries: those in Visconti Castle in Pavia, the Palace of Mantua, and the *studioli* of Isabella d'Este, the Ducal Palace of Urbino and Federico da Montefeltro's study, the library of Alessandro Sforza in Pesaro, the library of Sigismondo Pandolfo Malatesta in Rimini, and the Malatestiana Library in Cesena. Perhaps he was able to briefly inspect the libraries of Bembo and Grimani in Venice, the Vatican Library, and the royal library of Blois, where the Visconti-Sforza collections from Pavia and the Aragonese collections from Naples had been consolidated as spoils of war. He visited monastery libraries, especially in Florence: San Marco, Santo Spirito, Santa Croce, Santa Maria Novella, the Jesuates, Santa Maria del Carmine, Santissima Annunziata. He must have also slipped into the private libraries of humanists and literary figures he had befriended such as Fazio Cardano, Gasparo Visconti, the Marlianis, the Medicis, the Pandolfinis, and the Martellis, where he met bibliophiles and book hunters, such as Bernardo Bembo and Jean Grolier. Fragments of a universal library, of collective memory, are constantly threatened by the passage of time, war, the madness and the greed of humanity, as the tragic history of the ancient Library of Alexandria seemed to reveal to him: "Ammiano Marcellino claims that in the Battle of Alexandria in the time of Julius Caesar, seven hundred thousand volumes of books were burned" (*Codex Trivulzianus*, fol. 1v) (Fig. 3).

Fig. 3. Leonardo's note on Ammiano Marcellino's claim that "in the Battle of Alexandria in Julius Caesar's time, seven hundred thousand books were burned." *Codex Trivulzianus*. Biblioteca Trivulziana, Milan, 1487–1490, fol. 1v. Reprint: Brizio. 1980. Il Codice di Leonardo da Vinci nella Biblioteca Trivulziana di Milano. Florence: Giunti

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Fig. 3. Leonardo's note on Ammiano Marcellino's claim that "in the Battle of Alexandria in Julius Caesar's time, seven hundred thousand books were burned." Leonardo da Vinci. *Codex Trivulzianus*. Biblioteca Trivulziana, Milan, 1487–1490, fol. 1v. Reprint: Brizio. 1980. Il Codice di Leonardo da Vinci nella Biblioteca Trivulziana di Milano. Florence: Giunti

In his youth, Leonardo looked beyond the cultural and linguistic barriers of education and sought to rise to the cultural level of the scholars and humanists, university professors, physicians, physicists, mathematicians, and philosophers of natural science who are recalled again and again in his manuscripts, sometimes with notes and drawings in their own handwriting, often in connection with books to be looked at, consulted, borrowed, or returned. And yet his library was never the library of a humanist. In essence it remained true to its origins, as is attested by the preponderance of texts and authors from the Florentine popular and vernacular tradition of the 14th and 15th centuries. In contrast to the humanists and writers of his time, Leonardo developed an original and dialectical relationship to the *auctores,* the antique and modern authors (*altori*), and read their works free from the prescribed schema and constraints imposed by the observance of a principle of authority. Many of his books about natural science and natural philosophy conform to the cultural horizons of the scholasticism and Aristotelianism of the Late Middle Ages, but it is the intellectual image of the reader that is essentially new. Leonardo reads the *altori* from an "operative" perspective, selecting texts as problems arose from time to time in his research, interpreting them, contaminating them, and verifying them in light of *experience*, which shouldn't be understood as simple experimental evidence, but rather as the totality of methods in which theory and empirical practice are combined.

In the last years of his life, Leonardo once again shifted his attention from his beloved books, the *altori*, with whom he had been in (sometimes contentious) dialogue for many years, and turned his eyes to the heavens in order to observe the sun, the moon, and the stars. His eyes had been weakened by long nights awake by candlelight. Leonardo had to use eyeglasses, but because he had adjusted them empirically, they allowed him to enlarge images of distant objects: the moon, for example, which he observed from the rooftops of Rome in 1514. Up there in the heavens, there are more things than human philosophy can ever imagine.

Translated from the German by Amanda DeMarco

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Leonardo’s Worlds

Bernd Roeck

Fig. 1: Left: ca. 1516/17–1519. Portrait of Leonardo da Vinci. Francesco Melzi (attributed). Royal Library, Windsor, Inv.: RCIN 912726. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 (Life and Legacy H □). Right: Leonardo da Vinci ca. 1490, forensic reconstruction, Zurich 2018 (Grit Schüler, Forensisches Institut Zürich / Bernd Roeck, Universität Zürich[UZH]). Source: Bernd Roeck. 2019. *Leonardo. Der Mann, der alles wissen wollte*. Munich: C.H. Beck

Image:

Fig. 1. Left: ca. 1516/17–1519. Portrait of Leonardo da Vinci. Francesco Melzi (attributed). Royal Library, Windsor, Inv.: RCIN 912726. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 (Life and Legacy H □). Right: Leonardo da Vinci ca. 1490, forensic reconstruction, Zurich 2018 (Grit Schüler, Forensisches Institut Zürich / Bernd Roeck, Universität Zürich[UZH]). Source: Bernd Roeck. 2019. *Leonardo. Der Mann, der alles wissen wollte*. Munich: C.H. Beck

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A Man in Changing Times

After Picasso, Leonardo da Vinci is the most famous artist of all time. Only a few modern-day rock stars, athletes, and politicians manage to get more than the 144 million Google hits that are associated with Leonardo’s name. Still, he only left behind just over a dozen paintings, some of them unfinished and others in ruins—and even in this body of work, the attribution of some paintings is contested, such as the *Madonna Litta* at the Hermitage Museum in St. Petersburg, the *Portrait of a Musician* at the Ambrosiana in Milan (CR Lombardi, Fig. 1), and the second version of the *Virgin of the Rocks* at the London National Gallery.

In addition, there are over 6,000 sheets with text and drawings. They reveal the profile of a man who is universally educated and interested in everything. He presents himself as an engineer and technician; as an architect, anatomist, and astronomer; as a physicist, mathematician, geographer, and geologist; as an essayist and of course also as an artist. As a draftsman, he is among the best of all time. Finally, he also left behind notes: calculations, a vocabulary notebook, shopping lists.

The *Codex Madrid* contains the famous list of books and manuscripts that Leonardo da Vinci owned (4 □): 116 titles—that was more than some scholars around 1500 could call their own. Then there are also his letters and drafts of letters (47 □; 67 □). The original total inventory of manuscripts was estimated by some researchers at up to 30,000 sheets. Today they are spread across libraries, collections, and museums throughout half the world. This chaos contributed the mystique around Leonardo because much of what is only hinted at in the sources seems to indicate the contours of massive projects and great, innovative ideas. Mysteries remain, in any case, and mysteries tend to be more interesting than clarity.

The interpretation of the texts isn't complicated by the fact that Leonardo was left-handed, a *mancino*, and wrote in mirror-image script. The idea that he strove to hide the contents of his writing from prying eyes in this manner is among the many legends surrounding the man from Vinci. With a bit of practice and the help of a mirror, his writing can be readily deciphered. A much bigger problem is the fact that many of his notes are fragmentary and their original context and function is unclear. For example, was the "letter of application" to the Duke of Milan (67 □)—which exists only as a duplicate—ever sent? What audience did Leonardo envision for his flood fantasies (116 □), which are among his most impressive texts? And what should we make of this sentence, written down in 1510: "il sol non si move" (the sun doesn't move)? Of course, people try to make Leonardo the predecessor to Copernicus. But there is no shortage of evidence that his view of the world was a geocentric one that followed the cosmology of Ptolemy. Maybe these words, unconnected to anything else on the page, are stage directions for a theater performance?

In fact, in many senses Leonardo was more "medieval" that popular conceptions of his "genius" would like to admit. His optics are largely guided by doctrines advocated by the likes of Ibn al-Haytham—an Arab scholar who lived around the turn of the millennium. His physics is based on the writings of Aristotle, which were authoritative in the Latin Middle Ages; his medicine follows the teachings of the physician Galen of Pergamon (around 130–205/215). Through these studies and others, he came into contact with medieval interpreters, perhaps through lectures, perhaps also through conversations with experts. He had only a limited understanding of Latin and couldn't speak Greek at all.

Florence

Florence, however, where his precipitous rise began, offered opportunities for those who strove to acquire the patrimony of medieval and antique erudition. The city had ample libraries and in the second half of the 15th century it may have had the most stimulating intellectual atmosphere in the world. Humanistic culture was centered in this city on the Arno—in circles around the Medici, monasteries, in the palaces and gardens of merchants and the nobility. Commerce yielded wealth with which palaces were built, celebrations held, and scholars and artists were paid. Florence is in the center of Italy, and Italy dominated the center of the Mediterranean. It was a "sea of the future" just as the Pacific is today. Economic relationships aided far-reaching cultural exchange. Florence and Italy, with their knowledge-hungry, ambitious elites, profited from it. Earlier than other regions in Europe, people there used Arabic numerals—whose journey to the West began in India—and paper mills were also established early, after the world-changing material was invented in China over a millennium earlier. Florence was among the first cities where merchants practiced double-entry bookkeeping.

And here Roman law was the basis of the judiciary for centuries there before it was adopted across the Alps. It was probably the most consequential legacy of antique Rome. Its rationality fascinated anyone who was equipped with legal understanding and became acquainted with it. However, it required specialized knowledge that went far beyond the knowledge required for the old customary law. It demanded mastery of Latin, and some understanding of logic and dialectics. During the warm interglacial period that had led since the 11th century to population growth, urbanization, and an economic upswing, the number of legal transactions also grew dramatically. This increased the demand for trained lawyers; previously this work had been carried out almost exclusively by clerics. Now more and more laypeople were recruited. Around 1200 these conditions contributed to the creation of the first university in the world—along with the University of Paris—in Bologna.

A side-effect of this development was that lawyers came to form a broad secular educational class. Lawyers spearheaded the humanistic movement because they weren't only interested in digests, institutions, and glosses, but also the works of the poets and scholars of antiquity. Many greats of developing Renaissance culture, beginning with Petrarch, were born into families of lawyers; Leonardo also came from one—as did Machiavelli and Michelangelo.

Leonardo's father, Ser Piero d'Antonio, was a respected Florentine notary; the boy was born in 1452, the result of a brief liaison with a peasant girl. He probably largely grew up with his father in Florence—in the Drago *gonfalone* on the far side of the Arno. The sources do not support the idea of a youth spent in the countryside near Vinci. His father ensured that he learned calculation in an abacus school. Leonardo also never wrote in humanistic cursive, but rather in *mercantesca*, a script used by merchants, for example; occasionally forms slip in that were common in notarial documents.

Leonardo apparently had a good relationship with his father. Ser Piero ensured that he could complete an apprenticeship with the Florentine sculptor and painter Andrea del Verrocchio (1435–1488). Ser Piero probably had a hand in his first commissions, *The Adoration of the Magi,* for example. Sigmund Freud's assumption that the father saw himself as his son's competitor is just as untenable as the claim that the *Mona Lisa*'s smile harbors memories of Leonardo's mother for whom he supposedly felt erotic desire; even less sound is the ensuing thesis that it was this unfulfilled longing that caused him to become homosexual. In 1476 Leonardo actually was reported to the responsible authorities for "sodomy." This denunciation had no negative consequences for him; Florence's typically lax penal system allowed him to escape unscathed. Ser Piero's network of connections may also have helped.

What intellectual stimuli Leonardo may have encountered in his father's house remains a mystery. In any case, we know from the inventory of his estate that he owned 22 books protected by wooden bindings, though unfortunately not which books they were. If Ser Piero were the typical "humanistic lawyer," one could image that he was the one who gave Leonardo his first impression of the extraordinary patrimony represented by texts handed down from antiquity.

The Craftsman

In the beginning, however, was craftsmanship. Our fascination with the "universal genius" makes that easy to forget. The modern conception of the artist hardly existed at that time; painters and sculptors generally belonged to a guild and were subject to correspondingly strict regulations. Initially it was no different for Leonardo.

The fact that he also worked as a sculptor, as his biographer Giorgio Vasari (1511–1574) (Life and Legacy E □) claims, is certainly presumable since his master Verroccio had outstanding accomplishments in this area. No sculptures by Leonardo's hand were preserved, however—

or at least none whose attribution is uncontested. It is certain that he designed monuments. During his first Milan period in the final decades of the 15th century, he attempted to carry out a gigantic bronze casting of an equestrian statue for Francesco Sforza (68 □). The project failed, probably less due to technical problems than the military conflicts of the era. Duke Lodovico Sforza of Milan, Leonardo's patron, needed every pound of expensive bronze for cannons and not for art.

From the beginning, Leonardo's paintings stood in the foreground. Along with the *Adoration of the Magi* mentioned above, the *Madonna of the Carnation*, the *Benois Madonna*, and the *Annunciation* (17 □) mark the beginnings. He may also have contributed to some of Verroccio's paintings. From today's point of view, the art of painting demanded a nearly fantastic wealth of technical abilities. Those who did it had to be able to make brushes from the fur of squirrel tails, for example, which were cooked in order to pluck them more easily. He had to prime wooden boards, and he also had to know how to produce paints, lacquers, and glue.

The Verroccio workshop had little or no experience with the "al fresco" technique, in which paint is applied directly to still-wet plaster. But that isn't the only reason that Leonardo decided against using it on a large commission, the *Last Supper* in the refectory of the Convent of Santa Maria delle Grazie in Milan. More important was achieving the most vibrant colors and finest transitions. That is why he used *tempera grassa*—tempera with oil, which otherwise uses egg yolk as a binder—on a dry ground, *al secco*. This technique proved to be problematic. Leonardo worked on the painting over the course of two years, from 1495 to 1497. Soon after it was completed, the paint began to crumble away. After numerous restorations, very little "Leonardo" remains on the walls of the refectory today.

The first impression made by the *Last Supper* certainly must have been breathtaking. King Louis XII of France, whose troops occupied Milan in 1500, would have liked to tear it from the wall and have it transported to one of his castles.

The First Modern Artist

References to antiquity play an astonishingly small role in Leonardo's writings. Not once during his Roman years, between 1513 and 1516, does he seem to have studied ruins or statues particularly intensively; in any case very few drawings have been preserved, among them a hastily jotted down sketch of an Ariadne figure. His treatise on painting—a collection of scattered observations on his profession, preserved through later copies (Life and Legacy D □; Life and Legacy F □)—is nearly devoid of any engagement with ancient art. One reason may be that in his time it had long been self-evident that artists take antique models and develop them. Besides, he did adhere to criteria for good art that had been formulated in antiquity. They urged the imitation of *nature*—which didn't mean copying other works of art, not even those of the masters of antiquity. Otherwise, painters would merely be nephews, rather than sons of nature.

It was up to the artist to offer something original, something of their own. The painter's aim, according to Leon Battista Alberti, was "that his works be prayed to and he himself considered as a second God." Along with the architect, in the eyes of the humanists he was supposed to be knowledgeable in all of the liberal arts. This ideal had little to do with the craftsman's reality, besides the few painter-intellectuals like Piero della Francesca (84 □) or Andrea Mantegna. Leonardo was out to have his painting elevated to intellectual work. This is illustrated by an anecdote told by Vasari. The prior of the Convent of Santa Maria delle Grazie observed Leonardo lingering absentmindedly for half a day without making a brush stroke while working on the *Last Supper.* Seeing this, the prior wanted to prod him to work, as he would his gardener, and so he complained to Duke Ludovico about this supposedly lazy master. Leonardo then explained to the duke that “higher intellects” work most when they aren’t working—searching for ideas and forming a complete idea that can then be expressed through the work of the hands. Another punchline of the story is that in his mural, Leonardo gave Judas, the betrayer of all betrayers, who must have been the ugliest of the ugliest, the face of the friar who denounced him.

After the collapse of the Sforza regime, Leonardo took a few detours—*intermezzi* in Mantua and Venice that lasted just a few months—and returned to Florence. By now he could choose his patrons. For example, Isabella d’Este, the Marchioness of Mantua, tried in vain to get hold of a work by him. Leonardo was free to choose the theme, money was no object: she didn’t want a mere painting, she wanted a “Leonardo.” Acting this way toward painters or sculptors was extremely uncommon at that time. Normally they had to complete their work according to specifications that went down to the last detail. Contracts of the era stipulated which materials to use, particularly regarding the wickedly expensive gold and ultramarine. Leonardo also signed contracts of this kind in the beginning. The agreements for *Adoration of the Magi* and the *Virgin of the Rocks* have been preserved, among others. It is astonishing to note that the costs for gold or carvings at that time were approximately as high as the expense of executing the painting itself.

In 1503 in Florence, Leonardo began work on the *Mona Lisa* and *The Virgin and Child with Saint Anne*; at the same time the signoria commissioned him to adorn the great hall of the Florentine governmental palace, the Palazzo Vecchio, with a large mural of the *Battle of Anghiari*, in which a coalition led by Florence triumphed in 1440 over Milan’s troops. On the opposing wall, none less than a young Michelangelo was to paint a companion piece, the *Battle of Cascina*. In an era when foreign affairs were precarious, the depiction of these two battles that brought victory to Florence was intended to recall more glorious times. But the project ended in disaster. Leonardo had decided to use a process described in antique sources, encaustic. It promised brilliant coloration. The mixture, whose binding agent was wax, was difficult to handle, and it melted down the wall when Leonardo lit an oven under it in order to warm it and make it more elastic. At the end of 1505, he gave up in frustration and returned to Milan. While still in Florence, he had reactivated his relationships with the French court.

The mural, whose traces have been sought in vain beneath a fresco by Vasari, remained the most famous unpainted image in the world. From the *Battle of Anghiari*, only drafts and copies of a central scene remain, the fight for the Standard. It inspired later painters, including Raffael, Rubens, and Delacroix.

Courtier, Engineer, Tinkerer

Michelangelo didn’t deliver on his promise in Florence either, bigger prospects lured him to Rome. The triad of Leonardo, Michelangelo, and Raffael stands at the very beginning of a new era of art history and also the social history of art. In service of the court, as the protégés of princes, kings, and popes, they acquired freedoms, prestige, fame. In outline, they are the model of the modern artist. In this sense, Michelangelo stood out from the other two—with his brusque manner, his tics, his megalomania. With regard to the latter, Leonardo was his match. Many of his projects gesture toward the colossal. The bronze horse for the Sforza monument would have been the largest of its kind by far. The *cavallo* alone would have been no less than seven meters tall (the replica at the Milan hippodrome is something to be marveled at!). And at the beginning of the 16th century, Leonardo offered to build a massive bridge for the Ottoman sultan that would span the Lud (113 □).

A commission from Istanbul never materialized. It is astonishing, however, that in other cases he did manage to convince sponsors to back his megalomaniacal plans. At his suggestion, in the summer of 1503, the government of Florence began work on a gigantic canal. It was supposed to reroute the Arno away from Pisa, which was at that time occupied by Florentine mercenaries. But it proved to be far too labor-intensive. Thousands of gold *fiorini* were lost when the undertaking was cut short after a few months.

Leonardo must have been a very disarming person who knew how to convince patrons. Anyone who believes that Leonardo was a bearded, withdrawn thinker should consider that he probably only grew a beard in old age (the Turin portrait that shapes our image of his appearance to this day probably had nothing to do with Leonardo). Actually, the sources largely agree that he was a man of style. He dressed elegantly. For example, he occasionally wore a taffeta cloak or a deep violet coat with broad lapels and a velvet hood, accented with a rose-colored cap and black stockings—as a list from 1504 records it—and he owned another coat made of fine violet camlet , a doublet made of peacock blue satin, and shirts made of silk from Reims; we also know that he perfumed himself with rosewater or lavender. Should we believe certain (admittedly unreliable) sources, portrait sittings in his workshop—like Lisa del Giocondo's—were extremely comfortable. While the master, arrayed in the finest clothing, painted her likeness, a lute player and a fool are said to have entertained the lady. The anecdote explains art history's most mysterious smile in a way that, if nothing else, is less strained than Freud's abstruse speculation. Were Leonardo to approach us on the street as a revenant, he would seem more like a dandy to us than an introverted scholar.

Someone who met him personally—the humanistically educated physician Paolo Giovio—makes the following report on Leonardo's personality: "He was of a very friendly, cheerful, noble disposition, with a long and very graceful countenance. He was, at once, absolutely the arbiter of taste and above all the author of the most extraordinary pleasures, namely of the theater; he sang very beautifully to the lyre, which pleased all princes exceedingly no matter their age." Actually, Leonardo does seem to have also been a talented musician, an ability that is supposed to have earned him his first engagement at the Milan court in 1482. He also designed musical instruments, including a lyre shaped like the head of a dragon and a "viola organista" (CR Lombardi, Fig. 2), a cross between an organ and a violin.

At court there was a demand for people who could dispel boredom and keep melancholy at bay. The sources confirm the conclusion that Leonardo had a sense of humor. His books included an edition of the poems of the barber Domenico di Giovanni, pen name Burchiello (1404–1449), a Dadaist *ante litteram*, as it were; Domenico himself called his art "pirate poetry." It includes untranslatable puns and absurd associations. Domenico makes the moon speak, onions dance, and dogs howl "Halleluja!"; blackbirds ask: "What do these caterpillars have in their bellies that they're always shitting silk and eating leaves?" Leonardo himself made up funny vignettes and all sorts of anecdotes (48 □). Hundreds of rebuses in his hand have been preserved. For example, he sketches an hourglass and writes "ora" next to it—Italian for "hour," then a flautist with "sono" written under it: *suono*, meaning "I play"; spoken, it sounded like "sono," "I am." The third sketch shows a frying pan over an open flame: "fritto," "fried," or "finished." The solution is: "Ora sono fritto," "Now I'm finished!" With amusements of this kind, Leonardo could have entertained courtiers, and certainly his painter friends as well. Paolo Giovio also implies that he was assigned complex tasks: for the

Sforza court and later for the king of France, he organized dazzling parties and designed theater performances that, as contemporary sources describe it, must have been spectacular.

The fact that court society was dispersed may have also encouraged some technical gimmicks. Leonardo thought up apparatuses and made difficult-to-interpret drawings explaining their construction. For example, he designed an "automobile," a vehicle that was moved by the winding of a spring and whose direction of travel could be programmed. He produced instructions for building a robot: a knight that could move and wag its jaw. He tinkered with weapons and projectiles (122 □; 123 □), worked out construction plans for excavators—in connection with building the canals (127 □)—and hoists, and, to name a somewhat more obscure example, a roasting spit that was set in motion from the heat rising from the hearth. Sources report countless other pieces of handiwork, including a sheep's intestine pumped up like a hot air balloon. His real inventions include the ball bearing.

Leonardo may have been far prouder of his achievements as an engineer than of his paintings. In his day, engineers and architects enjoyed much higher social prestige than simple painters because they had to be familiar with mathematics and particularly geometry, one of the seven liberal arts. Craftsmanship, called *ars* in Latin just as art was, was *ars mechanica*, a mechanical art. In his aforementioned letter of application (67 □), in which he recommended himself to the Duke of Milan, he put special emphasis on his skills as a constructor of machines and as an architect. Louis XII of France spoke of him as "our ordinary painter and engineer"—that is, permanently employed painter and engineer.

Architect

At least in his early years, Leonardo lived from the sale of his paintings. Sometimes it happened that he simply had the idea for the composition, which was then carried out by employees. Be that as it may, his customers were buying "a Leonardo." The idea was the important thing, the product of his mind. This fits our estimation of Leonardo as the prototype of the modern artist. Jeff Koons works that way too.

During Leonardo's years at the Sforza court and in the circles of the French kings Louis and Francis, he would also have received pensions and honoraria for projects such as the theater piece mentioned above. When funds from Milan's treasure chest grew scarce, Duke Lodovico transferred a vineyard into his possession. Valued at 2,000 *lire imperiali*, the plot of land near the Convent of Santa Maria delle Grazie was very valuable. Leonardo bequeathed it to his long-time companion—and presumptive bedmate—Salaì, who was also often richly rewarded during the master's lifetime. Leonardo himself had inherited a wine-growing estate near Fiesole.

The extent of his wealth can no longer be determined. But it is certain that, at least in his early years, he never suffered from a lack of funds, except in his early years. Around 1500, he invested 600 gold *fiorini* at Ospedale Santa Maria Nuova, which, like other church institutions had the function of a depository bank. Such a sum would have been sufficient to buy a building in the center of Florence.

Architectural drawings were another source of income for Leonardo. During his early years in Milan, he produced plans for the new cupola over the crossing of the Milan Cathedral (124 □); later, around 1507, he created drawings for a villa for Charles d'Amboise, the French governor-general of Milan. The chapter in his life that we might title "Leonardo, architetto" left traces of numerous other projects, including designs for church façades, stables, and military installations. For Iacopo IV Appiani of Piombino, he delivered plans for defensive fortifications; one bunker looks as if it were created during the First World War. In his final years, which he spent as a guest of King Francis I near Château d'Amboise, he created sketches for a generously proportioned castle complex at Romorantin. Which of Leonardo's designs actually became buildings, however, is unknown. There is no proof that he is the mind behind the spectacular architecture of the Château de Chambord, as has been speculated.

Leonardo approached architectural planning armed with theoretical tools. His book collection included Leon Battista Alberti's *Ten Books on Architecture* (33 □), which was by far the most significant relevant text of the Renaissance. He made extensive excerpts from Francesco di Giorgio's book about military architecture, and he undoubtedly also knew Roberto Valturio's *On the Military Arts* (63 □). Both works were from the *quattrocento*; they also pass on knowledge from antiquity. For example, Leonardo became acquainted with the murderous "sickle car" in Valturio's writings: its wheels were equipped with sickles meant to lop off enemies' limbs. Valturio also mentions that balls of iron can be fired off using steam pressure. Leonardo took this as inspiration for building a steam cannon. He named it after Archimedes, who was attributed with the idea for such a weapon: "Architronito," the "Thunder of Archimedes."

The primary influence of antiquity on his work is documented in perhaps his most famous drawing, the "Vitruvian Man" (40 □) now kept in Venice. The sheet explains, with support from the authoritative Vitruvius—the only architectural theorist of antiquity whose work has survived—the proportions of the human body. They corresponded to musical harmonies. As Pythagorus (ca. 570–510 B.C.E) taught, they thus reflected the mysterious cosmic laws that determined beauty and harmony. Plans for how urban planning could be oriented around hygiene also betray a knowledge of Vitruvian teachings. Leonardo gave his duke a piece of advice that is very relevant in the current pandemic: "Such a great assembly of people, who stand one next to the other like goats filling everything with stench and sowing the seeds of the deathly plague, you shall sequester them from each other.

The "Philosopher"

In the language of his day, Leonardo was a *filosofo*. The term could mean a philosopher as well as a scholar. But he didn't care about book learning. He once wrote that he could be insulted as "an unscholarly man," (*homo sanza lettere*) (37 □). But that didn't bother him because he wanted to be a "student of experience." "Experience never errs. Only your judgments may be deceived by the promise of effects that have no basis in your experiments." He may have studied maxims such as this one in the authors of antiquity—as well as the principle of questioning and challenging that is the basis for the Socratic dialogue. He looked down on necromancers, magicians, and alchemists.

Leonardo wanted to get to the bottom of things. He described cloud formations, asked what clouds are made of, and wondered why they mass together. He pushed himself to describe a woodpecker's tongue and a crocodile's jaw. Farmers brought him fossilized seashells they'd found in the mountains; he wondered if they'd been swept there by the biblical Flood. But where could the water have drained away to in the less than two months budgeted by Genesis? Leonardo's answer: "Natural causes are missing here. Thus it is necessary, in order to dispel doubt of this wonder, to call for help, or to say that this water was evaporated by the heat of the sun."

Leonardo gathered experience by observing people and nature. He hiked through Tuscany and other regions of Italy, climbed mountains, and explored cities. And he took his notebooks with him, taking notes on all possible topics and making drawings: for example, various physiognomies and how they express certain emotions. In Imola, he produced the first precise city map in the world; he constructed a hodometer in order to measure distances. In Venice, he studied the tides, in Piombino the situation of the harbor and the color of shadows at sunset. His attempts to build flying machines are famous (57 □; 114 □). He tried to learn from birds and bats in order to make them. Numerous drawings and texts document his attempts to understand the physics of flight. He himself climbed church towers in order to gain familiarity with the workings of mechanical clocks with escapements—probably a 14th-century invention.

Leonardo's achievements as an anatomist were extraordinary. He is supposed to have dismembered 30 corpses. As he arrestingly described the gruesome business to be carried out: “If you have an inclination for such a thing, you will perhaps be hampered by disgust, and if that isn’t the case, you may perhaps be detained by fear of being in the company of such a quartered, skinned, horrifying corpse at night.” The results were astounding; into the 18th century, they remained by far the most precise anatomical studies in existence—worldwide, at that (69 □; 87 □). He ascertained the function of the sinews and muscles, cast the brain’s ventricular system with wax in order to investigate its shape, and pondered the function of the lungs, the excretory system, and the heart.

Leonardo seems to have intended to publish his anatomical drawings. The work was to include no fewer than 120 volumes. In connection with this plan, he invented a discharge printing process that would have been better suited to reproducing the fine details of his representations than copperplate or woodblock printing. But since he never published his anatomical studies—nor his other ideas, for example the ball bearings mentioned above—they had to be “reinvented” later.

Leonardo’s anatomy and many other studies he carried out went far beyond what would have been useful to him in his work as an artist or entertainer. An agent of Marchioness Isabella—the one who was supposed to convince Leonardo to paint a picture for her—wrote that he lived for the moment. He engaged intensively with geometry. His mathematical studies enticed him away from his painting, to the point that he no longer picked up the brush. He tirelessly considered the problem of squaring the circle. There are numerous drawings to prove it. “In the night of Saint Andrew’s Day I reached the end of squaring the circle,” he writes. “It was the end of the light and the night and the paper I wrote upon ... .”

The Creative Type

Of course he hadn’t solved the old problem. And most of his inventions were never faced with the test of practice—and never would have passed it. His flying devices never took off; most of his machines of war wouldn’t have worked. It should also be mentioned that he often asked very clever questions, but nearly as often his answers remained within the framework of traditional intellectual paradigms. For example, he made efforts to show that the moon had no influence on the tides and defended the position that astrological signs exerted powers and generated wind. Once he came very close to a highly significant insight. He asked if the blood flowing into the heart was the same blood that previously had opened its valves. But his answer to himself was “No.” So the discovery of the circulation of the blood was reserved for the Englishman William Harvey in the 17th century.

Reading through his notes often reveals a “nervous type” who broods over one problem and simultaneously sets his sights on a second one, all while taking up a third one on the side.

“His mind was never at rest, his intellect constantly invented new things,” an early biographer writes. Questions and insights intruded on his thoughts; he scribbled “memoranda” at the edges of his sheets—reminders to himself to look into something: “Dimme come ...,” “Tell me how ...” or simply: “Dimmi,” “dimmi,” “dimmi,” “Tell me, tell me, tell me ... .” Meanwhile, he was constantly swept away by questions and artistic challenges. It’s possible to trace his struggles to formulate things in his notes. Again and again he takes new approaches; sometimes things remain open-ended, but sometimes he arrives at sentences of captivating clarity. Take, for example, his definition of force: “Force is a spiritual energy, an invisible power that is generated by a sudden violence, that animates bodies supply to inanimate bodies, giving them a sort of life ... deceleration increases it, speed weakens it. It lives through violence and dies through freedom.”

In everything that he began, Leonardo was a perfectionist. That didn’t keep him from sketching and experimenting, but it did keep him from completing things and publishing them. As a painter, he also wanted his works to be perfect. And so he tried out promising processes, ones that he ultimately couldn’t bring to fruition. That is why the *Last Supper* decayed, and the completion of the *Battle of Anghiari* failed for the same reason. Vasari summarizes: “But in truth his mind, being so surpassingly great, was often brought to a stand because it was too adventuresome, and the cause of his leaving so many things imperfect was his search for excellence after excellence, and perfection after perfection.” In a few individual cases, he did manage to master the most difficult of problems. The desire to achieve the famed *sfumato* posed enormous challenges: the production of smoky, gentle transitions from lighter to darker parts. In order to achieve the best possible effect, Leonardo experimented tirelessly. Along with the never completed *Virgin and Child with Saint Anne*, the results were the *Mona Lisa* and *Saint John the Baptist*, perhaps Leonardo’s final painting. From a technical perspective, these two works are nearly perfect. There is hardly a brush stroke to be recognized on them, the bodies seem modeled like reliefs, landscape fades into a distant blue. In the case of the *Mona Lisa*, which he may have worked on for years, he put down approximately 30 ultra-thin layers of glaze. Vasari had this painting in mind when he celebrated Leonardo as the founder of a new era in art history.

Martin Kemp, one of the greatest connoisseurs of art by the master from Vinci, says that it is not astounding that Leonardo painted so little, but rather that he finished anything at all. The painter didn’t just work his fingers to the bone on technical problems. Just as the *filosofo* was hardly in control of his ideas, he must also have been beset by a flood of images. He once once said that before he fell asleep at night, he recalled the forms he’d studied during the day in order to imprint them into his memory. Many of his texts end in a myriad of imaginative descriptions of images. The mysterious flood fantasies (116 □) that he drafted in the final years of his life provide grandiose panoramas that could perhaps be realized as computer simulations but could not be implemented as real works in his time.

Notion of Humanity and Belief

Leonardo is among the most mysterious men in the history of the world. The fact that the historical record is incomplete and chaotic is in large part responsible for this man of flesh and blood being glorified as a mythical figure. Paradoxically, the sources reveal more about his way of thinking and creative work than any other artist of the Renaissance, making us witnesses to a long-since vanished existence. His notes indicate a way of life that was neither humble nor luxurious (though he did keep horses). They mention wine, which he drank in the morning, certainly diluted with water, along with purchases of all sorts: parsley, mint, and thyme, wine vinegar and salt, bread. Meat is occasionally mentioned, along with partridges. Was he actually a vegetarian, as some sources claim? In fact, vegetable fare did dominate his table: the sources name green beans, millet and peas, buckwheat, mushrooms, eggs, and ricotta cheese, along with bitter oranges, grapes, and mulberries.

The image of Leonardo's personality is contradictory. As has been said, he had a sense of humor; but there are also sources that portray him as an inscrutable melancholic. One of his essays suggests the very antithesis of the "Renaissance man," as the 19th century tended to interpret him. He doesn't portray people as creators, but rather as destroyers of their world. "Beings will be witnessed on earth which ceaselessly combat each other, with great losses and widespread death on either side. There will be no end to their evil. Through the wild force of their limbs, a great part of the trees of the universe's great forests will be felled. And once they have reveled, the fulfillment of their longing will be to bring death and sorrow and travail and fear and flight to all that lives. And in their measureless arrogance, they want to elevate themselves to the heavens. But the excessive weight of their limbs will pull them downward. Nothing will remain on the earth or beneath it or on the water that is not pursued or eliminated or ravaged or carried from one land to another."

Leonardo was in a likelihood not a Christian. Whether he renounced his heresy and accepted the Catholic faith on his deathbed on May 2, 1519 in Amboise is a matter of dispute. In comparison with other libraries, theological books are underrepresented in his collection. God is rarely mentioned in his writings. "I obey you, Lord," he once wrote, "first because of the love that I reasonably owe you, and second because you are able to shorten or lengthen the life of man." That doesn't sound particularly pious. Leonardo believed that the soul consisted of the finest material, the "fifth element" (*quinta essentia*). Since, according to the teachings of antique physics, all elements strive to return to their source—water and earth are pulled downward, fire and air upward—after the dissolution of the earthly body, it must float up to the heavens. In Leonardo's understanding, the soul wasn't searching for God up there, but rather traveling to a realm beyond the moon that, according to ancient belief, consisted purely of quintessence. A sentence that Leonardo cites from the Presocratic Anaxagoras can be interpreted that way: "Everything comes from everything, and everything is made out of everything, and everything returns into everything, because whatever exists in the elements is made out of these elements." In this way of thinking, the soul dissolves into the world soul, losing its individuality.

Leonardo's vision of the end of the world offers a scenario that seems nearly prophetic: "The rivers will be without their water, the fertile earth will no longer bring forth budding branches and fields bedecked with billowing grain. All animals will die because they will find no fresh grass on which to graze, and so [too] will the predacious lions and wolves and other creatures of prey lack nourishment. And after much resistance, the people will be forced to leave this life, and the human race will die out. And so the fertile, fruit-bearing earth will remain forsaken and desolate, dry and infertile, because the sap of its waters is sealed in its belly … and the cold, tenuous air must pass into the element of fire. And then its surface will remain burned to ash and that will be the end of earthly nature." There is no mention of the of the Last Judgment or hope of eternal salvation.

Translated from the German by Amanda DeMarco

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Leonardo’s Left-handedness

Carmen C. Bambach

The Writer

While to the connoisseur’s eye the physical effects of Leonardo’s left-handedness are among the most immediately noticeable characteristics of his drawings and manuscripts, the signs of his condition as a *mancino*—a left-hander, “lefty,” or “southpaw,” in modern words—were judged very differently by his contemporaries.

Renaissance culture paid particular attention to the appearance of a calligraphic hand (Figs. 1–2). The well-proportioned beauty of a *littera antiqua* (*lettera antica*), or an initial of elegant flourish, were the signs of a refined humanist education, while the predictable clarity and regularity of a simple, quick cursive *alla mercantesca* identified the practical work of the professional ranks of notaries, judges, lawyers, and merchants (16 □; 18 □; 19 □; 20 □). Leonardo’s contemporaries and early biographers could plainly see evidence of his left-handedness in his script, a more or less practical *mercantesca* type, but one that courses from right to left in so-called mirror-writing in the overwhelming majority of his manuscript notes, and in the fact that many of his notebooks were filled with content and foliated by him, from the back to the front of the volume, or quire. Although in mirror direction, his *mercantesca* cursive in identified writings of the 1470s to early 1480s somewhat resembles that of his father, Ser Piero da Vinci.

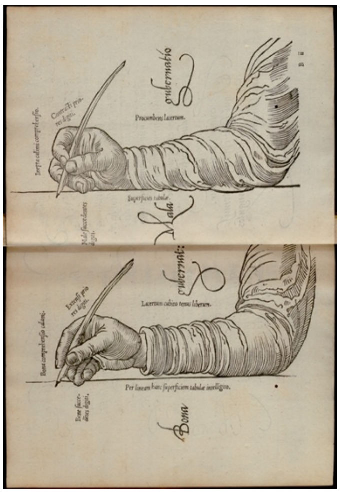

Fig. 1. Shown here are the incorrect (top) and correct ways of holding a quill pen for writing, the “mala gubernatio” and “bona gubernatio.” Gerard Mercator. 1540. *Litterarum latinarum, quas Italicas, cursoriasque vocant, scribendarum Ratio*. Löwen, Unpaginated. Bayerische Staatsbibliothek Munich, Res/4 Graph. 83#Beibd.2, Sheet 10–11. urn:nbn:de:bvb:12-bsb00026193-9

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04_Bambach_bottom_01

Fig. 2. Giorgio Vasari, a left-hander writing into a book held with the right hand (study for St. Luke in the destroyed altarpiece for Pisa cathedral), ca. 1542–43. Black chalk, 9.5 x 16.2 cm. Gabinetto Disegni e Stampe degli Uffizi, Florence. 6439 F r

Image:
04_Bambach_02

Leonardo appears to have been relatively aware of his left-hander's habits. In one of his earliest autobiographical passages, probably written in about 1480, he referred to his left hand as the "tired hand" ("la stanca mano"), in the old metaphoric sense also used by Dante. In 1504–1505 he described a novel printing method for his written text, "del gittare in istanpa questa op[er]a" (*Codex Madrid II*, fol. 119r), and knowing that the process of printing letters and images would naturally invert the direction of a mark, he clarified: "cover the iron plate with egg white and then write in the left-handed manner," meaning write from right to left, "scratching that surface" ("metti la piastra dj ferro. di biacha a uovo e poj scriui a mancina / sgraffiando tal canpo"). A slight sketch in red chalk of about 1514–1516, perhaps by Melzi, and on the coarse paper of light brown-beige color with porridge-like fibers of Leonardo's late period, portrays a left hand holding a quill in the act of drawing or writing (*Codex Atlanticus*, fol. 770v). This is probably the hand of the master at work.

Fig. 2. Giorgio Vasari, a left-hander writing into a book held with the right hand (study for St. Luke in the destroyed altarpiece for Pisa cathedral), ca. 1542–43. Black chalk, 9.5 x 16.2 cm. Gabinetto Disegni e Stampe degli Uffizi, Florence. 6439 F r

Leonardo's left-handedness has far-reaching implications for the reconstruction of his artistic personality. It ultimately helps to explain the tragically unrealized dimension of his career as an unpublished author. The gamut of his habits of writing as a *mancino*, together with the sheer quantity of manuscript needing retranscription into a conventional left-to-right direction of text, would have presented insurmountable obstacles for most early modern publishers of books. Moreover, as will be seen, the text in his manuscripts is often greatly fragmentary in narration, even in his mature writings of most advanced redaction. Not surprisingly, the actual publication of Leonardo's writings in any complete sense of the original text began only in the 19th century, and was facilitated by the use of reproductive photography. Until the 1880s and 1890s his fate was to be paraphrased, diluted, and severely excerpted, rather than to be quoted directly, and *in extenso*.

Even the best early interpreters of Leonardo's handwriting ran into problems. Melzi was the main scribe-author of the Codex Urbinas Latinus 1270 (Biblioteca Apostolica Vaticana), who compiled the incomplete *Libro di pittura* after Leonardo's notes, as shown by samples of his handwriting (Life and Legacy D □). Working on the redaction of the *Libro* (perhaps in the 1520s to 1540s), Melzi, who himself possessed an elegant humanist cursive in his maturity, lamented that "the work on this half chapter is ruined, an error that occurred because the script was left-handed [*la lettera ch'è mancina*], and because the half chapter was jumbled up on another page [written] in the opposite direction." More than anyone, Leonardo's pupil, scribe, and artistic heir labored directly from his master's manuscripts, often also annotating them. As will be seen, Melzi's role was frequently to be Leonardo's right-handed interpreter and scribe, particularly during the master's old age in France, when he was partially crippled. Melzi also sought to imitate Leonardo's manner of drawing precisely, down to the left-handed parallel hatching of the originals, in some of the minute pen-and-ink illustrations of the Codex Urbinas Latinus 1270. Giovanni Paolo Lomazzo (1538–1600 in

1584 and Paolo Morigia in 1619 praised Melzi as an accomplished miniaturist in his own right (“grandissimo miniatore”).

Although Leonardo is today the most universally famous left-handed artist of all time, even a revered “poster child” for this quality in the popular imagination, the fact that he was a *mancino* stood out greatly in the Renaissance, and not in a positive sense, since being left-handed had some age-old social, cultural, and psychological connotations. His left-handedness no doubt became conflated with early, prosaic myths regarding his “secret” endeavors. He was an unusually unreformed *mancino*, who does not seem to have retrained himself into the habit of using his right hand for writing or drawing, although he attempted conventional left-to-right script on certain occasions (more on this below). He is in all of this a unique figure. The natural left-handedness of other important artists did not define them, nor has it been considered to be an especially prominent fact of their biography, or of their work.

Among the earliest of those to record Leonardo’s left-handedness was not a biographer, but one of his closest friends, Fra’ Luca Pacioli of Borgo San Sepolcro (ca. 1445/50–1517 (78 □), the Franciscan mathematician who became his tutor, frequent collaborator, and traveling companion. Pacioli, it will be seen, emerges as another of the unsung heroes in the biography of Leonardo. He was no more than seven years Leonardo’s elder, and arrived in Milan in 1496. It is possible they knew each other before 1496 (the year of Pacioli’s summons by Ludovico Sforza “Il Moro“ to Milan, to teach Euclidean geometry), given the *frate*’s peregrinations throughout the peninsula in the 1470s and 1480s as a teacher of mathematics. He is documented not only at Borgo San Sepolcro, but also in Rome, Perugia, Zara, Naples, Milan, Florence, Pisa, Bologna, and Venice. He settled in Venice in 1494, to supervise the publication of his *Summa de arithmetica geometria proportioni et proportionalità* (74□) at Paganino de’ Paganini’s printing press. Leonardo’s and Pacioli’s rich professional interactions were intertwined at various times during the early 16th century, until 1514–1515 in Rome (Bambach 2019d).

Pacioli’s *De viribus quantitatis* (MS, 1496–1508), a treatise on the power of numbers, repeatedly states that Leonardo was *mancino*. Most importantly, it is clear Pacioli spoke from firsthand knowledge. Folio 239v in De *viribus quantitatis* describes how Leonardo “wrote in reverse, [his script] is left-handed, and which could not be read unless with a mirror, or really by holding the back of the sheet against the light. As I understand, and can say, that is the practice of our Leonardo da Vinci, lantern of painting, who is left-handed.” Pacioli’s *De viribus* also alludes to Leonardo’s collaboration with him in 1496, stating that the artist prepared and drew the studies of geometric solids “with his ineffable left hand,” to illustrate the *De divina proportione*. The surviving archaeological evidence, however, suggests a more complex picture. Although not previously observed, most of the beautiful drawings themselves of the regular and semiregular polyhedra, illustrating Pacioli’s manuscript *De divina proportione* (Milan, Veneranda Biblioteca Pinacoteca Ambrosiana S. P. 6) (Fig. 3) (86 □), are obviously done in pen and blackish-brown ink with right-handed, diagonal, parallel hatching: in many of these designs, the strokes course from lower left to upper right, or from upper right to lower left. As finally realized, their style and technique of execution do not resemble Leonardo’s drawings on paper. These facts as a whole seem to exclude Leonardo’s actual authorship of the final drawings in pen and ink with color on the vellum of Pacioli’s Ambrosiana manuscript, although Leonardo was certainly their “conceptualizer.” The amanuensis finally producing the Pacioli illustrations probably derived outline designs from the matrix of Leonardo's drawings of the geometric bodies by means of tracing techniques.

Fig. 3. Right-handed artist, Plate XLV: a solid square column in Fra Luca Pacioli's manuscript *De divina proportione*, ca. 1499. Pen with brown, blue, and black ink, brush with watercolor and gouache, over stylus ruling and traces of leadpoint, on vellum. Milan, Veneranda Biblioteca Pinacoteca Ambrosiana, S.P. 6. akg-images / Mondadori Portfolio / Veneranda Biblioteca Ambrosiana

Image:
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Fig. 3. Right-handed artist, Plate XLV: a solid square column in Fra Luca Pacioli's manuscript *De divina proportione*, ca. 1499. Pen with brown, blue, and black ink, brush with watercolor and gouache, over stylus ruling and traces of leadpoint, on vellum. Milan, Veneranda Biblioteca Pinacoteca Ambrosiana, S.P. 6. akg-images / Mondadori Portfolio / Veneranda Biblioteca Ambrosiana

Leonardo's icosidodecahedron (*Codex Atlanticus*, fol. 707r), outlined in pen and brown ink, over a preliminary *spolvero* (dotted chalk) underdrawing may represent such a matrix design: it is one of three autograph outline drawings on *spolvero* that is in the actual scale of Pacioli's Ambrosiana manuscript illustrations. His other related drawings of geometric bodies are *Codex Atlanticus*, fol. 708–709. (Fig. 4). At any event, Pacioli's *De viribus* is, therefore, one of the very rare Renaissance sources to mention overtly Leonardo's left-handedness as a draftsman. Filled with praise for Leonardo, Pacioli's *De divina proportione* is perhaps his most famous treatise and ranks as one of the finest expositions of Euclidean geometry of the early Renaissance. While it was written between about 1496 and 1498, it was not published until nearly a decade later, on June 1, 1509, in Venice by Paganino de' Paganini, who was also the publisher of Pacioli's *Summa*.

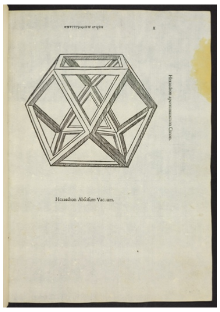

Fig. 4. Pacioli, Luca. 1509. *Divina proportione: Opera a tutti glingegni perspicaci e curiosi necessaria*. Venice: Paganini de Paganinis. Venedig: Paganini de Paganinis. 4°. Plate X. Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Nu 7780a (75 □) Photo: Marvin Müller

Fig. 4. Pacioli, Luca. 1509. *Divina proportione: Opera a tutti glingegni perspicaci e curiosi necessaria*. Venice: Paganini de Paganinis. 4°. Plate X. Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Nu 7780a (75 □) Photo: Marvin Müller

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The early accounts of Leonardo's left-handedness are most complete regarding his activity as a writer, which is not surprising, given the obvious visual impact of "mirror script." Vasari's corrected 1568 edition of the *Vita* of Leonardo (following his visit to Milan in May 1566) stated that among the large portion of the master's anatomical drawings and notes owned by Melzi was a "notebook drawn in red chalk and hatched in pen," of anatomical dissections done in collaboration with Marcantonio della Torre (Bambach 2019c, chap. 10). It illustrated the skeleton, nerves, and muscles, and next to these drawings, "part by part, he wrote in letters of an ill-shaped character, which he made with the left hand, backwards; and whoever is not practiced in reading them cannot understand them, since they are not to be read save with a mirror." The Aretine biographer added that, besides the material owned by Melzi he perused in Milan, some writings on painting by Leonardo—"with letters written with the left hand, backwards"—were also owned by a "pittor milanese," who visited Vasari in Florence with the intention of enlisting his help in getting Leonardo's manuscript published. Since Vasari's printed text has a blank space for the Milanese painter's name, art historians have speculated that this collector of Leonardos was either Giovanni Paolo Lomazzo, Aurelio Luini, or Gerolamo Figino, who was Melzi's main pupil, as has been seen.

Lomazzo's *Trattato* of 1584 records that Leonardo wrote for Ludovico Sforza his book on the comparison of the arts, or *paragone*, with the "tired hand" ("egli scrisse di mano stanca"). It is probably a firsthand account of the original (now lost) manuscript. A few years later, Lomazzo's *Idea del tempio della pittura* of 1590 likened Leonardo to a lion ("al Vinci ho dato il leone"), considering him to be the most noble and imitated among all painters, his art full of knowledge, "as one can see from many volumes written and drawn by him *alla mancina*."

Early and modern authors have endeavored to explain the reasons why Leonardo wrote in an unconventional, right-to-left script, and here is where fact has joined myth, for, to quote the words of a late 17th-century author:

> Vinci used to write in a left-handed manner [*alla mancina*], according to the practice of the Jews, this being the manner in which those 16 volumes are written that we have already mentioned, and the character [of the writing] being good, it could be read rather easily with the means of a large mirror; it is probable that he did this, so that not all could read his writings so easily.

This explanatory note was written on a front flyleaf (fol. 2v) within the Roman red leather binding of the *Codex Leicester*. It dates between 1690 and 1717–1719, from the time that Leonardo's coveted manuscript was in the hands of the painter and collector Giuseppe Ghezzi. This note by Ghezzi, or his scribe, expands upon the statement handsomely written on the title page (fol. 2r), which similarly alludes to Leonardo's left-handed script. The gist of this wording from Ghezzi's binding was also retained for the inscription on the new cover commissioned by Thomas Coke, who purchased the volume directly from Ghezzi in the first half of 1717. Considered precious, every little tidbit of Leonardo was passed on like a relic.

Natural Handwriting versus Code Writing

The popular imagination has loved mysteries and "secret codes," and some authors have misleadingly suggested that Leonardo's right-to-left script was cryptographic writing to hide the secret contents of his work. This makes little sense, and such claims are misinformed in view of actual Renaissance practices of ciphered or code writing. The most widespread use of it was in political correspondence. True code writing of this period is usually recognizable by the small series of disruptive numbers or letters or other kinds of ciphers imbedded within words or sentences. The extant records of correspondence (*copia lettere*) kept by the secretaries of Pope Leo X, who reigned from 1513 to 1521, include a thick gathering of 77 pages filled with tables giving the different glossaries of code ciphers (letters, numbers, or combinations thereof) for people, places, and things mentioned in the papal letters to 54 individuals (ASF, Manoscritti Torrigiani, *filza* 2, *fascicolo* 16 [in its entirety]). These glossaries of code ciphers varied according to the correspondents, and these included patrons known to Leonardo, such as Lorenzo II di Piero de' Medici (no. 22) and Antonio Maria Pallavicini (no. 34; see Bambach 2019c, chap. 11–12).

A well-known example of "quasi-code writing" by Leonardo is the so-called "Ligny Memorandum," from either about 1494–1495 or, much more likely, about 1499–1500, which records a secret journey to Rome and Naples through enemy territory, with Louis de Luxembourg, count of Ligny (1467–1503), and cousin to Charles VIII of France. Leonardo wrote a long block of text in his normal right-to-left script, but knowing his reader would expect to read him in a specular sense (right to left), he purposefully gave the spelling of four significant names and words in the first two lines of text with letters in inverted order, or, for a right-handed reader, actually in the conventional left-to-right direction. He thus wrote, if one reads him right to left: *ingil* (for "ligni" = Ligny), *morra* (for "rroma" = Rome), *ilopanna* (for "nnapoli" = Naples), *enoiganodal* (for "la donagione" = the donation). For plain fun, Leonardo delighted in designing rebuses, cryptic pictographs, and puns. In the rebus puzzles, however, he usually provided the clues, removing all mystery: he drew the tiny pictographs and then clearly identified these below with corresponding text.

A strong ludic character runs through some of his activities and is manifested further in his numerous "facietie" (bawdy farces) recorded here and there in his manuscripts (48 □), in his doodles and sketches of grotesque heads, or in his copious drawings and procedural exercises in transformational geometry in his late years. On a few occasions, he also expressed his general concern about safeguarding the secrets of his technological research, particularly military. His *Paris MS G*, of about 1510–1511 and 1514–1515, describes his secret methods in building a burning mirror, or "ignia" and many of the crucial ingredients are given special names and these are also spelled code-like backwards, that is, in left-to-right direction embedded in his usual right-to-left text (Bambach 2019c, chap. 11).

However, Renaissance engineers, like Bonaccorso Ghiberti (grandson of the great sculptor Lorenzo), relied on much heavier code writing in order to protect trade secrets: the drawings and many recipes in Bonaccorso's *Zibaldone* (45 □), compiled from 1472 to 1483, and revised in the 1490s, are inscribed with a profuse series of discordant numbers, letters, and periods in the text; the most famous illustrations therein record the great machinery invented by Filippo Brunelleschi for the *cantiere* (building yard) of Florence cathedral (30 □). It is obvious that Leonardo's normal, right-to-left script was not intended at all to function as a type of "secret writing," because it was habitual and is readable to anyone, given enough practice. The painter and scholar Matteo Zaccolini of Cesena (1590–1630) became so absorbed by his studies of Leonardo's original manuscripts that, according to the personal notes of his friend the erudite Cassiano dal Pozzo (1588–1657), "the said Matteo got used to that kind of [mirror] writing and began writing many of his own notes in that manner with great facility and in well-formed script, so that no one could at first understand them."

The closely contemporary woodcut and drawing, by Gerard Mercator and Giorgio Vasari respectively (Figs. 1–2), illustrate the good and bad habits of handedness in writing. Vasari's powerful study in black chalk depicts the left-handed model writing with a quill pen in an especially contorted pose. For Leonardo, his manner of writing in right-to-left direction was comfortable, clearly a function of practicality, and followed the natural rhythm of his hand; modern scientific research suggests that for "lefties" mirror-writing may come more easily than conventional left-to-right script. The pen moves with less effort and stays ahead of the writing, without smearing the ink. It is also evident—to judge from the fluent, expository manner of Leonardo's writings, their elegant structure of reasoning, their copious quantity, and the attractive calligraphic styles of some of his early notes—that he could not have suffered from dyslexia, as is time and time again asserted in popular journalistic writings. His habit of right-to-left writing was continuous throughout his life, and was manifest early. The inscription at upper left on the recto of the famous *Arno Valley* landscape drawing (18 □) is dated August 5, 1473, done when he was 21 years old. Whether Leonardo could also write extensive text in conventional left-to-right script was the subject of especially heated debate among early scholars. The consensus now is that he did, in the case of short text, though on remarkably few occasions. The verso of the early *Arno Valley Landscape* drawing is scribbled on at the top in an attractive calligraphic hand with a conventional, although somewhat strained left-to-right script that may also possibly be by the young Leonardo.

Work in a Right-handed World

One can learn a great deal about the emphasis on righthandedness in the Renaissance from popular printed calligraphy books of the period (they are often also illustrated with modest woodcuts), but this type of source is rarely tapped by historians. The illustrations and the detailed instructions of such manuals shed light on the mechanics of holding and moving a pen and ink on paper, and the sum of the evidence argues not unexpectedly for a right-handed world. Gerard Mercator's *Literarum Latinarum* (Antwerp, 1540) (Fig. 1), for instance, actually portrays the correct and incorrect ways of holding a quill pen in writing, and most calligraphy books advise on how to maintain a steady posture of the body, as well as the ergonomic pose for the arm, right hand, and fingers, chiding that the pen be moved only in three strokes.

Leonardo's left-handedness, however, would have presented a challenge to his writing teachers, especially on account of the awkward placement of the hand around the quill (for example, curling the hand and wrist above the line to be written or below it), as is seen in Vasari's drawing (Fig. 2), which was necessary for conventional writing. The manuals give various recipes for inks, papers, and sizing, and describe how to make well-crafted quill pens for achieving the elegant, rapid movements necessary for the cursive script (with attractive "legatura" and "incatenatura"). As these popular books state, the best quill feathers were plucked from a domestic goose ("ocha domestica"), although a wild goose would also be suitable, but from the bird's right wing so that the angle and curve would correspond to a right-handed writer (the tip then required cutting according to precise instructions). The calligraphy book by Marcello Scalino da Camerino, entitled *Regole nuove et avertimenti* (Venice, 1584; Brescia, 1591), also describes step by step how right-handed boys were taught handwriting. But, it is clear from Giovanni Francesco Cresci's *Perfetto scrittore* (Rome, 1570) that teachers gave up on the "defects" of some of their pupils.

While one can imagine that left-handedness was considered a severe shortcoming, the fact that Giovanni Battista Palatino's enormously popular calligraphy book (Rome, 1540) actually illustrates a clever pattern for practicing a "lettera mancina" (literally, left-handed script, meaning in a right-to-left direction) indicates that left-handed script was a curiosity, but not unheard of. Palatino's woodcut is inscribed below with a rhymed verse telling that the writing can be read without straining the mind, with the aid of a mirror. A great variety of scripts was also acceptable. Giovanni Antonio Tagliente's *Excellente scrivere* pattern book (Venice, 1532) even illustrates a model for practicing a "lettera pendente," that is, a conventional left-to-right cursive that leans to the left in an exaggerated way as if it were left-handed (as opposed to the conventional rightward tilt), which many master calligraphers deplored.

One may speculate freely that Leonardo's childhood was not defined by ordinary patterns of schooling, since he was of illegitimate birth and lived outside the paternal household until about 1464–1465, when he was 12 to 13 years old. The 1568 edition of Vasari's *Vita* describes the transgressions of the young Leonardo as a pupil: "at the *abbaco* school during the few months that he attended it, he made such progress, that he often confounded his teacher by continually raising doubts and causing difficulties." While the degree of veracity of Vasari's anecdote may be questioned, in that it is a *topos*, intent on showing the precocity of the boy Leonardo's genius, it is unlikely to be a complete fabrication. Notaries were among the Renaissance professionals most required to possess the skill of a quick, self-confident cursive script, often not devoid of flourishes. Their ideal was to write with a light hand ("lo scrivere con la mano leggiera").

At first his boy's writing *alla mancina* may have vexed Ser Piero da Vinci, whose profession as a notary depended on good, rapid calligraphy. In any case, *abbaco* schools (attended by youths between 11 and 14 years of age) followed the course of reading and writing, and were mainly dedicated to business mathematics ("leggere, scrivere et abaco"); they served as the training ground for the future ranks of merchants, bankers, accountants, and notaries (some artists and artisans of the building trades also attended them.). While the young Leonardo acquired the skills of good script, either on his own, tutored by his family, or from formal education (since both Latin and vernacular schools in the 15th century taught writing), he did not retrain himself, as Michelangelo did after 1500, to write a beautiful humanist cursive.

Leonardo had a fine eye for calligraphy from the beginning. Although in right-to-left direction, his early handwriting, as in a sheet dated by him 1478 when he was 26 years old (Florence, Uffizi GDS 446 Er), is pleasingly ornate, and his initials often exhibit attractive flourishes. Of similarly pleasing ductus are the small words written in right-to-left script as calligraphic warm-up exercises along the right border on another drawing of this time (London, British Museum 1860,0616.100r). The verso of this sheet, from the late 1470s or early 1480s, contains the sketches relating to the *Benois Madonna* and the *Madonna Litta* (St. Petersburg, State Hermitage Museum). It would have also concerned Leonardo in his later career as author of treatises that his contemporaries judged the education of a Renaissance humanist by the quality of his antique-style lettering and script. As one knows indirectly, around the years 1498–1502 he prepared the designs for the woodcuts of the alphabet of Roman epigraphic letters published in Pacioli's *De divina proportione* in Venice in 1509 (fol. Aii recto, "tanto ardore vt schemata quoq.sua Vinci nostri Leonardi manibus scalpta").

If Leonardo's left-handedness was thought to be noteworthy in the Renaissance, it has also fascinated posterity; small wonder, since both ancients and moderns have speculated widely on what generally causes left-handedness. While Plato blamed it on "the folly of nurses and mothers" (*Laws*, VII: 794), modern scientists in the fields of neurobiology, psychology, and anthropology continue to this day to seek answers about the phenomena of handedness in human beings and animals. Sigmund Freud wrote in a letter of October 9, 1898 to his disciple Wilhelm Fliess (1887–1902) that "perhaps the most famous left-handed individual was Leonardo, who is not known to have had any love affairs." Freud preposterously equated Leonardo's left-handedness with his sexuality. He pressed on this and other points forcefully in his famous psychosexual interpretation of Leonardo's personality based on a "childhood memory" (published as *Eine Kinderheitserinnerung des Leonardo da Vinci*, Leipzig and Vienna, 1909–1910).

Of all the explanations given (from the sublime to the ridiculous), the simplest and most convincing is that Leonardo was innately left-handed. His copious manuscripts reveal his effortless facility in writing from right to left, his cursive pouring forth fluently, rapidly onto the paper. It was probably a further privilege of his left-handedness that, when developing ideas in his drawings, he possessed the uncommon ability as an artist to reverse the design of motifs, figures, and entire compositions inside his head, as though they were reflected in a mirror. This feature of his creative process has been substantially overlooked. One can name significant cases in which the preliminary sketches of an intended composition offer designs in both a leftward and a rightward orientation—the so-called "Madonna of the Cat," the *Adoration of the Magi*, and the *Virgin and Child with St. Anne*.

His design practice offers a parallel for the fact that mirrors were for Leonardo a potent tool in his work as an artist and theorist. Mirrors reflected nature, and were, therefore, the teacher of all painters, as stated in a note of about 1490–1492 in the Paris MS A, intended for the *Libro di pittura*. He also compared the work of the painter to the reflection in a mirror, as is clear from a lost note for the *Libro di pittura*, of around 1500–1505, preserved in the Codex Urbinas Latinus 1270. He conducted complex experiments with concave mirrors to prove the existence of constant and parabolic curves. During his years in Rome (1513–1516), serving Giuliano de' Medici, he described the optics of mirrors, in addition demonstrating "Alhacen's problem" (how one relates the actual placement of an object to its reflection in a curved mirror). The science and mystery of mirrors were abiding themes in his work as an artist and "non- artist."

The Left-handed Painter and Draftsman

The early written sources raise interesting questions regarding Leonardo's handedness as a painter. The famous description in the diary entry of October 10, 1517 by Antonio de Beatis alludes to Leonardo's paralysis of the right hand, a text that scholars have interpreted in a variety of ways. De Beatis, who was secretary to Cardinal Luigi d'Aragona, recorded that he and his employer visited Leonardo in his living quarters at Amboise (Life and Legacy H □). In giving his eyewitness account, de Beatis also commented: "quite true, that, because he [Leonardo] was overcome by a certain paralysis of his right, one can no longer expect fine things from him ... *messer* Leonardo can no longer paint with the sweetness of style that he used to have, and he can only make drawings and teach others." It is not necessarily true (as is often claimed) that Antonio de Beatis made a mistake regarding Leonardo's handedness. It is only natural for an artist to engage much of the body in the physical act of painting, and, most likely, the implication in de Beatis's text is that Leonardo probably relied on his right arm and hand for balance and support in painting with his left. Handedness is also often relative. For the 65-year-old Leonardo suffering from ill health, in contrast, the paralyzed right hand was not a matter of impairing his skill in terms of precision, since one knows that he was primarily left-handed, but of taxing the physical strength of his arms in the demanding act of painting.

Lomazzo's *Idea del tempio della pittura* of 1590 enigmatically notes in discussing the great master's perfectionism, "so it seemed that Leonardo trembled each hour that he set out to paint." Lomazzo's *Trattato* also refers to Leonardo as a lefthanded painter with the phrase "pittore di mano manca" (*mano manca*, for the left hand, literally "lacking hand"), along with numerous admiring citations of his genius. Evidence of his left-handedness in his paintings is more subtle, however, and is best appreciated in his unfinished compositions. Parallel-hatched brushstrokes *alla mancina*, coursing from lower right to upper left, or from upper left to lower right, are very sporadically visible in some passages of the underdrawing and early stages of modeling with aqueous medium in the Uffizi *Adoration of the Magi* and Vatican *St. Jerome*.

The 19th-century "scientific" drawings connoisseurs, who insisted on making attributions based on an empirical method, sometimes at the expense of documents and technical evidence, all singled out Leonardo's left-handedness as a critical factor in establishing the authenticity of his drawings. The most prominent figures in this history were Giovanni Morelli (1816–1891), who used the pseudonym Ivan Lermolieff, Jean Paul Richter (1847–1937), and Bernard Berenson (1865–1959). While it is today well accepted that Leonardo's drawings and handwriting offer a concrete basis for assessing his left-handedness, more precise observations of an archaeological nature can be offered, without generalizing too categorically.

In acknowledging that Leonardo was left-handed, one may ask whether he might have been ambidextrous as a draftsman, that is, a left-hander who at times used his right hand. Some ambidexterity among artists is not unusual. Regarding Leonardo, this question occasioned heated dispute, even "mudslinging," among some early connoisseurs. Anglo-American art historians, the present writer included, have tended to agree on an exclusively left-handed Leonardo as a draftsman, but this view carries consequences. One of the most iconic images by him is a drawing that has almost always been accepted as autograph: the boldly executed cartoon in Oxford (Christ Church 0033 [JBS 19]). It depicts a grotesque man in bust-length profile and dates from about 1503–1505, precisely during the moment of work on the *Battle of Anghiari*. It exhibits a preponderance of right-handed hatching, and only minimal areas of left-handed strokes, mostly concentrated in the man's back.

In 2003, I thought it might not be impossible to envision Leonardo's drawing with both hands—at least in the instance of large-scale cartoons, since they usually require a very physical way of drawing, engaging the entire body of the artist. But now it seems far likelier that the right-handed passages in the Christ Church cartoon were done by a pupil, who was being closely supervised by the master. Complicating matters, the drawing surface of the Oxford cartoon was also substantially reworked by early right-handed restorers.

Science Aids Art History

The analysis of Leonardo's drawings with scientific means has a relatively short history (it more or less begins with fits and starts in 1947), and has led to particularly successful results in the case of his silverpoint drawings that have become invisible or faintly visible (Bambach 2019a, chap. 3–4). The refinement of new scientific instrumentation and techniques of analysis also continues to revolutionize the way connoisseurship is done by art historians. The material analysis of Leonardo's inks deserves, and has often received, particularly detailed attention, since pen and ink was his most abundantly used medium throughout his career.

In the case of his draftsmanship, in which the various physical details that distinguish his originals from the numerous copies count so much, the topic has developed in fascinating complexity, with the application of science. To state the question broadly, are there material distinctions in the inks in some originals with respect to the copies? This may well be in some cases. The National Gallery of Art in Washington, D.C., owns both of the relevant examples that could be tested with identical instrumentation and protocols, to ensure consistency and control of variables: Leonardo's original of the grotesque head of an old woman (Fig. 5**)** from the Chatsworth series, and Melzi's nearly exact copy of this same drawing (Fig. 6) from the Pembroke series, in which the grotesque woman is portrayed as part of a couple. The enlarged photographic details published here illustrate the modeling with lower right-to-upper left hatching in the two drawings, for Melzi reproduced faithfully if somewhat scratchily Leonardo's left-handed strokes of hatching. The preliminary conclusions regarding the Washington pair of drawings by Leonardo and Melzi are telling. Since Leonardo's original is drawn with iron gall ink, it disappears entirely when examined in infrared light, while the design in Melzi's copy does not seem to disappear much in infrared light. It indicates that if iron gall is present, it is in a mixture with a great amount of something else, probably carbon. Future research will undoubtedly help refine these findings, for the very young field of scientific research regarding Leonardo's drawings is vastly promising.

Fig. 5: Leonardo da Vinci, *Old woman with horned headdress, wearing a carnation, in bust-length profile view* (detail) from the Chatsworth series of grotesques, 1490–1500. Pen and dark brown (iron gall) ink. The Woodner Collection 74585 (Promised Gift of Dian Woodner in Honor of Earl A. Powell III), on deposit at Washington, D.C., National Gallery of Art. Courtesy National Gallery of Art, Washington D.C.

Fig. 5: Leonardo da Vinci, *Old woman with horned headdress, wearing a carnation, in bust-length profile view* (detail) from the Chatsworth series of grotesques, 1490–1500. Pen and dark brown (iron gall) ink. The Woodner Collection 74585 (Promised Gift of Dian Woodner in Honor of Earl A. Powell III), on deposit at Washington, D.C., National Gallery of Art. Courtesy National Gallery of Art, Washington D.C.

Image:

Fig. 6: Giovan Francesco Melzi derived his drawing from Leonardo's original and reproduced meticulously his master's left-handed technique of hatching. Melzi after Leonardo da Vinci; *Couple in bust length, facing each other* (from the Pembroke series of grotesques). Pen and brown (carbon) ink, over traces of black chalk. Washington, D.C., National Gallery of Art 1980.63.1 (Gift of Mrs. Edward Fowles). Courtesy National Gallery of Art, Washington D.C.

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Fig. 6: Giovan Francesco Melzi derived his drawing from Leonardo's original and reproduced meticulously his master's left-handed technique of hatching. Melzi after Leonardo da Vinci; *Couple in bust length, facing each other* (from the Pembroke series of grotesques). Pen and brown (carbon) ink, over traces of black chalk. Washington, D.C., National Gallery of Art 1980.63.1 (Gift of Mrs. Edward Fowles). Courtesy National Gallery of Art, Washington D.C.

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This essay is a short excerpt taken from Carmen C. Bambach: *Leonardo da Vinci Rediscovered*, Yale University Press, 2019, vol. 1: *The Making of an Artist 1452–1500*, 39–63; its scholarly apparatus can be found in volume 4 of this comprehensive work (pp. 58–68).

RECOMMENDED READING

———. 2019a. *Leonardo da Vinci Rediscovered*. Vol. 1: *The Making of an Artist 1452–1500*. 4 vols. New Haven / London: Yale University Press.

———. 2019b. *Leonardo da Vinci Rediscovered*. Vol. 2: *The Maturing of a Genius 1485–1506*. 4 vols. New Haven / London: Yale University Press.

———. 2019c. *Leonardo da Vinci Rediscovered*. Vol. 3: *The Late Years 1506–1519*. 4 vols. New Haven / London: Yale University Press.

Bambach, Carmen C. 2019d. *Leonardo da Vinci Rediscovered*. Vol. 4: *Scholarly Apparatus to Volumes One, Two, and Three*. 4 vols. New Haven / London: Yale University Press.

Leonardo and Print

Jochen Büttner

In 1452 Johannes Gutenberg embarked in enormous project in Mainz, Germany, that would take him the next three years to complete—to use his recently developed printing press and metal cast movable-type to print the first major book, a Bible of no less than 1,282 pages in folio. On April 15 of that year, the day the first sheet of the Gutenberg Bible may have left the press, Leonardo was born in a small town in Tuscany.

In the following years, printing with movable type spread with overwhelming speed all over Europe. It brought far reaching and consequential transformations to the late medieval world. Leonardo was born into a world changed by print. He is a child of the printing revolution.

Leonardo’s library serves as the most obvious outward sign of the changing world in which he lived. A collection like his, comprising over 200 books, would have been unthinkable for a person of his status in the age of scribes during which every exemplar of a book had to be copied by hand. It has indeed been estimated that approximately 1,000 copies of a book could be printed for the price of three scribal copies of the same text, making books in Leonardo’s time, albeit still expensive, much more affordable.

In the second half of the 15th century, more and more books were being printed for an ever-widening market. The increase in printed material allowed knowledge to be disseminated further and faster and to reach new audiences. Books granted Leonardo access to works of historic and contemporaneous authors even though he had not had the opportunity to attend university. Bibliographical aids that made it easier to find and reference information, like title pages with essential bibliographical information, tables of contents, indices, and page numbers, were first introduced and became standard in books only as a consequence of printing.

Rulers and members of the nobility started to collect printed books and opened up their libraries to the scientists, engineers, architects, and artists, such as Leonardo, for whom they acted as patrons. It generally became much easier to find a copy of any given work and the distances one had to travel in order to consult a particular book shrank considerably. Thus, Leonardo's book consumption was not limited to the texts he personally owned, as he frequently consulted other collections. In notes, he reminds himself to “try to see Vitolone which is in the library at Pavia” (Witelo) or to “get the Friar of the Brera to show you the *De Ponderibus*” (*Codex Atlanticus*, fol. 611r).

The rise of print also had indirect consequences for Leonardo. For instance, he became thriftier with his use of paper over time, which has been attributed to the scarcity of paper on the general market as a result of the high demand of paper by printing presses. Leonardo also progressively formatted pages in his notebook that seem to mimic the layout of contemporary books.

The printing revolution was by no means completed during Leonardo’s lifetime. It remained somewhat common for books to be reproduced and circulated as manuscripts rather than printed copies. For example, a hand-copied treatise by Francesco di Giorgio Martini on architecture, engineering, and military art, was part of Leonardo’s library. Leonardo’s personal copy with annotations in the margins, most likely made by himself, is still extant today (66 □).

Yet, printing and the printing press did not only influence Leonardo through the social changes they engendered. Rather, he became directly involved with the new technology. Leonardo's interest in mechanics, in all types of machines, and in automation is well known. All possible mechanical contrivances, even seemingly insignificant ones, caught Leonardo's attention. He sketched them and, more often than not, puzzled over possible improvements, including the printing press. His notebooks are overflowing with sketches of machines, both real and imagined, some of which have become iconic of Leonardo's creativity (118 □; 119 □; 120 □; 126 □; 127 □).

There is hardly any mechanical technology of his day that he did not contemplate, be it on paper or through actual construction. His notebooks, moreover, include multiple assertions of his desire to draw commercial profit from his inventions. It is thus only natural that book printing, one of the most prolific areas of early modern capitalistic enterprise, sparked Leonardo's interest.

Throughout his life, Leonardo had ample opportunity to visit printing shops and to experience and study the process of book printing. During his formative years in Florence (Life and Legacy B □), the first printing press opened in the town in 1471, and others quickly followed. Printing was even more omnipresent in Milan. Leonardo moved there in 1481 (Life and Legacy C □), and worked at the Sforza court for nearly two decades. In these years, print shops were mushrooming across northern Italy; nowhere else did printing spread so rapidly at that time. In 1500 he sojourned in Venice(Life and Legacy D □), which had become the printing capital of Italy with at least 150 printers (5 □). Upon his return to Florence in that same year, the print emporium of the Giunti family, who operated presses, warehouses, and bookshops not only in Florence but all over Europe, was just coming to full bloom.

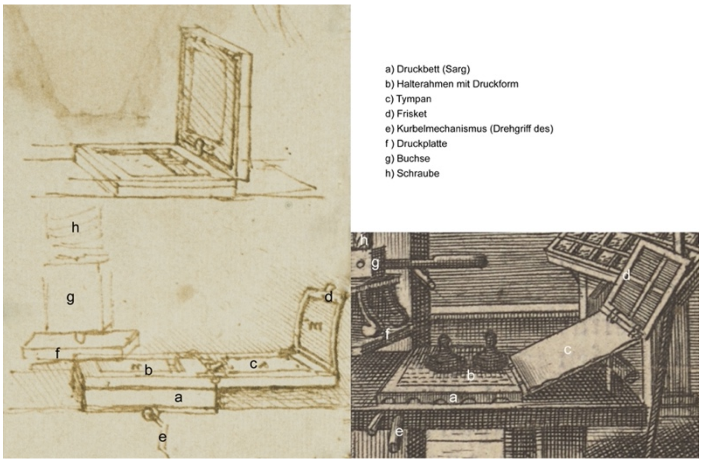

Fig. 1. Left: Schematic sketch of a printing press by Leonardo drafted presumably around 1495. The upper part shows a detail of the same press at a different stage of the printing process. Leonardo da Vinci. ca. 1497. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1038r (detail) (126 □). Right: Detail of a woodcut illustration of a printing press in a book of 1651. Saavedra Fajardo, Diego de. *Idea Principis Christiano-Politici. 101 Sijmbolis expressa*. Amsterdam: Iacobum van Meurs. Sheet 4a (detail). Letters have been added to the individual components to facilitate comparison. Graphic elements have been removed from the detail of Leonardo's folio that are not relevant to both drawings. Left: Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti. Right: National Gallery of Art Library, Washington, D.C. David K. E. Bruce Fund

At least three sketches of printing presses have been preserved in Leonardo's notebooks, testifying that he indeed studied and reflected about printing intensively and even sought to improve the technology. In fact, these sketches are the earliest known visual representations of printing presses at all. They precede the earliest depiction of a printing press to be found in a printed book, *La grant danse macabre des hommes et des femmes* from 1499. The oldest actual printing presses that have been preserved date from around 1600; thus, they are more than a century younger than Leonardo's sketches.

Folio 1038r of the *Codex Atlanticus* contains a particularly detailed sketch of a printing press, presumably drafted around 1497 (126 □). Other early known representations of presses generally lack detail. Therefore, to better understand Leonardo's drawing, we must compare it to a somewhat later rendition of a press, printed in a book from 1651 (Fig. 1). The illustrations from this book have been juxtaposed with Leonardo's drawing, and letters have been added to facilitate the comparison and to identify individual components from the text. The strikingly similar renditions reveal two key points: More than 150 years after Leonardo produced his sketch, the printing press remained virtually unchanged, and Leonardo had obviously studied the technology in quite some detail.

Fig. 1. Left: Schematic sketch of a printing press by Leonardo drafted presumably around 1495. The upper part shows a detail of the same press at a different stage of the printing process. Leonardo da Vinci. ca. 1497. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 1038r (detail) (126 □). Right: Detail of a woodcut illustration of a printing press in a book of 1651. Saavedra Fajardo, Diego de. *Idea Principis Christiano-Politici. 101 Sijmbolis expressa*. Amsterdam: Iacobum van Meurs. Sheet 4a (detail). Letters have been added to the individual components to facilitate comparison. Graphic elements have been removed from the detail of Leonardo's folio that are not relevant to both drawings. Left: Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti. Right: National Gallery of Art Library, Washington, D.C. David K. E. Bruce Fund

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In the center of Leonardo's drawing, we see the coffin, or printing bed (a), carrying a frame (b) that holds the forme of type to be printed. Fixed to the bed by means of hinges is the so-called tympan (c), a frame covered with parchment upon which the sheet of paper to be printed is placed. Attached to the tympan by hinges is a light frame, the so-called frisket (d), covered with a paper from which the printable area has been cut out. Once the paper has been positioned on the tympan, the frisket is folded over to hold the paper in place and to prevent areas not to be printed from being blemished. Leonardo indicated this stage in the upper sketch.

Tympan and frisket, together, are then folded onto the inked frome. Finally, the bed with the frome is rolled under the press by a windlass mechanism called the rounce. The rotating handle (e) driving the rounce is clearly visible in Leonardo's drawing. Of the actual press only the platen (f), which exerts pressure on the paper, and the hose (g), which keeps the platen steady while the screw is turning are shown. The screw (h) is only suggested. A similar contemporaneous sketch that shows the press itself in somewhat more detail and from a different angle can be found on fol. 991v of the same codex.

Such a press would have been operated by two men: the inker, who inked the frome, and the puller. The puller placed the paper, turned the handle of the rounce with one hand, and, once the bed was under the platen, pulled the bar or spindle on the screw with the other hand to apply the pressure and execute the print.

It is obvious from these sketches that by 1495 Leonardo had studied current print technology in great detail. The third drawing, also in the *Codex Atlanticus* (fol. 995r) (13 □; CR Essay Wallbach), shows that Leonardo had already begun to wrap his inventive mind around the question of improving the press and further automating the printing process some 15 years earlier. The drawing, which was made when Leonardo was still in Florence, is split into two parts that illustrate two possible improvements to the printing press. The left sketch shows a press equipped with a double action screw, allowing for quicker up and down motion of the platen. The right sketch shows an interesting construction in which the movement of the print bed is mechanically coupled to the motion of the pressing screw. The rotation of the screw is transferred to a spool by means of two crown wheels and a vertical shaft. The spool winds a rope pulling the bed, which seems to be set on wheels, underneath the platen and, after the impression has been made, unwinds the rope again. Since the bed is placed on a slight slope, it will thus roll back all by itself.

Clearly, Leonardo aimed to improve the efficiency of the printing process, by further automatizing and accelerating it. Printing presses in Leonardo's time are estimated to have produced about four impressions per minute. Despite the rapidity of the printing process compared to hand copying, printers still faced considerable limitations in possible output and needed to justify labor with potential profits. To fully appreciate the need for increasing print efficiency, one should briefly visualize the immense number of operations that printing a book required. In order to print a 500-page book in a run of 2,000 copies, for instance, one million pages must be printed in total. Even though this would be a rather thick book with a rather high print run, such figures were certainly achieved at the time. Furthermore, it is estimated that by 1500, after only 50 years of printing, at least nine million books had been printed across Europe. Less conservative estimates even claim a figure of 20 million. Every improvement that would have helped to render the printing process more efficient would have been deeply welcomed by the printers, who were constantly seeking ways to make their enterprises more profitable. Leonardo's proposals for the press, like so many of his other proposals, did not make it into praxis, and the printing press remained more or less unaltered until the introduction of all metal industrial printing presses around the turn of the 18th century.

Leonardo did not consider printing as merely one technology among many. Rather, he declared it as the most important technology of his day in a note under his sketch of an automated loom, "This instrument is second only to printing and not less use" (*Codex Atlanticus*, fol. 356r).

It is often repeated that not a single work by Leonardo was submitted to the printing press during his lifetime, despite his passionate interest in it as a mechanical device. The statement, however, is not fully correct and needs qualification. Leonardo was indeed printed, not as an author but rather as what would today be called an illustrator of a book, in *De divina proportione* by the mathematician Luca Pacioli (75 □).

Pacioli had been teaching mathematics at various universities when he accepted an invitation in 1497 by the duke of Milan to teach mathematics at his court. Leonardo may have been instrumental in this invitation. His notebooks prove a longstanding interest in mathematics, but also that he had difficulty mastering it. Furthermore, he owned a copy of Pacioli's *Summa de arithmetica, geometria, proportioni et proportionalita* (74 □), which had been published in 1494. We know that Leonardo had indeed read the book, as he summarized parts thereof in his own notebooks. At one point, Leonardo even reminded himself to “learn multiplication of the roots by master Luca” (*Codex Atlanticus*, fol. 331r).

It is worth noting that the *Summa* was written in vernacular Italian (*volgare*), and thus was the first ever printed work on algebra not written in Latin. Pacioli’s earlier work *Tractatus mathematicus ad discipulos perusinos*, a thick textbook for teaching mathematics, had also been written in Italian (in contrast to what its Latin title may indicate), but it only circulated as a manuscript. Only a short time before, it would have been unimaginable to issue such books in the vernacular. However, the second half of the 15th century saw a trend in which vernacular languages began to replace Latin as the dominant language of writing. This trend, which emerged largely due to the new way of distributing texts via printed books, certainly suited Leonardo who had learned to read Latin rather late in his life.

During the three years they spent together in Milan, Leonardo and Pacioli became friends and developed a productive work relationship, characterized by their deep mutual admiration and respect for one another. Pacioli gave Leonardo lessons in mathematics and in the course of their joint discussions would certainly have learned a lot from Leonardo about the application of mathematics and geometry in art and architecture. The latter topic is a central theme of the project Pacioli undertook in this period—the writing of *De Divina Proportione.*

The expression *divine proportion*, which Pacioli coined himself, refers to the golden ratio. The golden ratio had already been studied by ancient Greek mathematicians, most notably by Euclid. The work addresses more than just the golden ratio. It also deals with a general theory of proportions, which played a central role in the increasing mathematization of knowledge in the Renaissance.

Altogether Pacioli produced three manuscript versions of the work. Two of these manuscripts are still extant, each penned by different scribes but both supplemented with what are believed to be original illustrations by Leonardo. One is housed in Milan (86 □); the other, with a dedication to the duke of Milan, Ludovico Sforza, is preserved in Geneva. The third manuscript, which is lost today, had been given to Pier Soderini, a high civic magistrate of the Republic of Florence. When the work was finally edited, printed, and published by the Venetian press of Paganino de Pagani almost ten years later in 1509, it, too, was dedicated to Soderini (75 □).

The book had quite some impact in its day. It is made up of three parts. The first part, titled *Compendio dela divina proportione,* begins with about 20 chapters devoted to the golden section. The following about 50 chapters address numerous regular and semiregular polyhedra, which discuss them in terms of geometry, their neo-platonic and symbolic aspects, and their role in architecture. The second part is a treatise on architecture, based on

Vitruvius (31 □). The third part is essentially an Italian translation of Piero della Francesca’s *Libellus de quinque corporibus regularibus.* It deals with the five simple, regular polyhedra, which Plato, drawing on Pythagorean ideas, associated to the primary elements that made up the Earth and the heavens. Even though Piero della Francesca had been Pacioli’s teacher, he is not credited as the author.

Lastly, there is an appendix of illustrations comprised of two sections. The first section contains the letters of the alphabet constructed by Pacioli using a ruler and compass. The letter M served as the iconic logo of New York’s Metropolitan Museum of Art until 2016. The second section contains more than 60 woodcut illustrations that were based on Leonardo’s drawings in the manuscript versions of the work. The woodcuts vary slightly from the manuscript drawings. For instance, the polyhedra in the manuscripts hang on ropes whereas the printed versions float midair (Fig. 2).

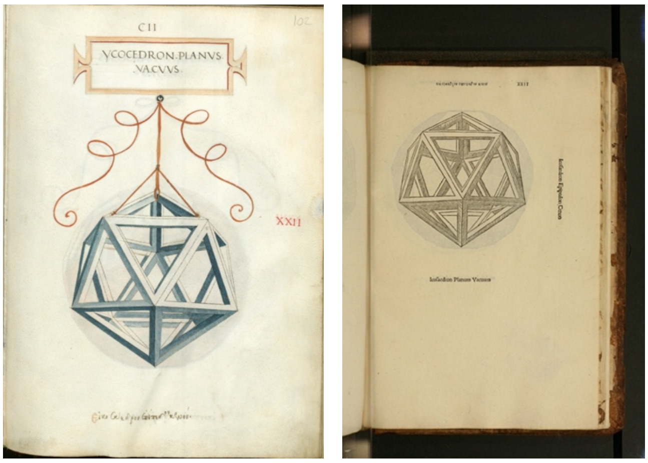

Fig. 2. Left: Leonardo’s drawing of the rod-model of one of the platonic solids, the regular icosahedron, in a copy of a manuscript by his friend, the mathematician Luca Pacioli (Biblioteca Ambrosiana, Milan, S.P. 6). Right: The same figure as a woodcut illustration in Luca Pacioli’s *De divina proportione*, printed in 1509. Pacioli, Luca. 1509. *Divina proportione: Opera a tutti glingegni perspicaci e curiosi necessaria*. Venice: Paganini de Paganinis. Plate XXII, Shelfmark: 4° 47289. Left: akg-images / Mondadori Portfolio / Veneranda Biblioteca Ambrosiana. Right: Getty Research Institute, Los Angeles, CA / Internet Archive, San Francisco

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Pacioli praises Leonardo and his “incomparable left hand” several times in the book and fully acknowledges Leonardo’s contribution in the following passage:

> And the figures you have above in this [book] together with all the others from the hand of our exquisite Florentine compatriot Leonardo da Vinci, whose drawings and figures could never with truth be contested by any man.

These words ultimately leave no doubt that Leonardo was, in fact, printed during his lifetime.

The conversion of *De divina proportione* from a book that originally circulated as a manuscript to a printed book mirrors the ongoing transition from scribal to print culture at the time. The power of printing in establishing a text's enduring significance is exemplified by the fate of another Pacioli work, which was possibly also produced in cooperation with Leonardo. *De ludo scachorum* (On the game of chess) was not printed and was subsequently lost for over 500 years.

In 1500 Leonardo and Pacioli briefly resided in Mantua (Life and Legacy D □). They had moved there after the Duchy of Milan had been conquered by the French king, Louis XII, leaving Leonardo without a patron. The *De ludo scachorum* seems to have been conceived around this time. Referring to the treatise in another work, Pacioli stated his intention to dedicate it to Isabella d'Este, Marchioness of Mantua, who is said to have been a chess enthusiast herself.

The exact nature of Leonardo's contribution to *De ludo scachorum* remains debated. In the manuscript, more than 100 chess problems are treated, and each problem is accompanied by a rendition of a chessboard with the respective positions of the pieces. The pieces themselves are not rendered as mere ideograms, as was common in chess books then, but as actual pieces. Their appearance, however, is atypical for chess sets of the time, and it has been argued that Leonardo created the unusual designs. The drawings in the manuscript were made by two different hands; Leonardo was possibly one of the artists. It has even been speculated that Leonardo himself contributed some of the chess problems collected in the work. Others have contested the involvement of Leonardo in the project whatsoever.

The game of chess became very popular in the medieval period and was associated with high social prestige; it was a common activity in the circles Leonardo and Pacioli frequented. Books on the game of chess were among the earliest books to be printed. The *Game and Playe of the Chesse*, published in 1474, was the second book ever to be printed in English language. Based on a medieval predecessor, it is less an instruction on the actual game but uses chess as an allegory for social order.

In the last quarter of the 15th century, the medieval rules of the game, which often differed slightly from place to place, were superseded by a new mode of playing. In particular, the move possibilities of the queen were greatly extended, making the games shorter and sharper. The new way of playing was called *alla rabiosa* in Italian, which freely translates to "mad queen chess." The rules introduced at that time are essentially the rules we play today. About half of the problems in *De ludo scachorum* are based on the old version, and the other half addresses the new rules.

The natural medium for the spread of the new rules would have been the book, just as letterpress printing contributed to unification and standardization in many other areas during this period. It is therefore not surprising that Pacioli sought to have the *De ludo scachorum* printed. In 1508 the Venetian Doge granted Pacioli's request that only he himself could publish his works within the Venetian republic for the next 15 years. This permission included his book on chess. Pacioli quite obviously understood the new opportunities offered by the press; he has been referred to as the prototype of a modern popularizer, his medium being the printed book.

For whatever reason, Pacioli never printed his book on chess; others were left to disseminate the *alla rabiosa* rules in print, most notably Damiano de Odemira in *Questo libro e da imparare giocare a scachi et de le partite*, published in Rome in 1512. Moreover, Pacioli's manuscript was lost for more than five centuries, giving rise to speculations that, despite Pacioli's remarks to the contrary, it had never been written in first place. Yet under curious circumstances, the manuscript was finally rediscovered in 2006 in a library collection in northern Italy. Under less fortuitous circumstances, it could just as easily have been lost forever.

A perfect example of the precariousness of keeping single or only a few copies of important documents is seen in Leonardo's own collection of ideas on paper. It is estimated that Leonardo filled about 30,000 pages with notes and drawings of which only about a quarter have survived to the present day. He was fully aware of the perils of keeping single copies of handwritten notes. Around 1506, after his return to Florence, he jotted down a note to himself:

> Tomorrow look at all these cases, then copy them and cancel the originals and leave them in Florence, in order that if you should lose those which you are carrying with you, the invention will not be lost. (*Codex Atlanticus*, fol. 571r)

An obvious solution would have been to hand his works over to the printing press. Leonardo presumably planned to publish on multiple subjects, as evidenced in several of his notebooks. For instance, the Codex Leicester includes a plan for a "Book of water" (CR Essay Schneider). Torn between his many interests, Leonardo was never able to finish one of these publication projects. Given his fascination for the printed book and book printing, there can be little doubt that Leonardo would have immediately handed a work over to the printing press had he ever managed to complete one to his own satisfaction.

If he had handed a work over to a publisher, rendering his graphic-oriented work would have proved a major challenge in this early phase of printing. The printing of images predates the onset of book printing with movable type in Europe. Two techniques were, in principle, available to capture his intriguing drawings on the pages of a printed book: woodcut and engraving. Towards the end of Leonardo's life, etching became a third possibility.

In woodcut printing, the parts of an image that are not supposed to be printed are carved out from a block of wood. The design left on the original surface level carries the ink and becomes the print. Woodcut printing was imported to Europe in the 13th century from China. Initially, it was used for textile print. With the increased availability of paper, it became quite popular in the early 15th century and was used, for instance, to print playing cards but also occasionally books, which required entire pages of text to be tediously carved out of the woodblock together with the illustration. As a relief printing technique, woodcut could easily be combined with movable type, once the latter had been introduced. Indeed, both techniques were quickly merged to allow the text along with its decoration or illustration to be printed in a single operation. The *Mainz Psalter* (1457), the second major book after the famous Gutenberg Bible to ever be printed, already contains woodcut initials. In 1467 the German printer Ulrich Hahn, who ran a printshop in Rome, printed the first woodcut illustrated book in the Italian states.

The cutting of the woodblocks was a difficult task reserved to specialists, who first transferred the design, usually made by someone else, to the block and then cut it. The woodcut prints Dürer produced beginning in the last decade of the 15th century testify to the perfection that could be achieved with this technique (76 □). However, Dürer must be considered an exception; the carving and printing of woodblocks faces serious limitations. In order to print a line, the artisan must cut its negative. A clear and well-defined line is therefore rather difficult to achieve, particularly when many lines intersect, for instance, in cross hatching used for delicate shading. Moreover, the finer the line, the higher the risk that the rib would break away in printing. As a consequence, early woodcuts used in high print runs showed rather thick lines and not much shading or texture.

Upon closer inspection, the illustrations in *De divina proportione*, which had been executed and printed in woodcut, reveal some notable errors compared to the earlier versions of Leonardo's manuscript illustrations. Leonardo was indeed skeptical if woodcut print could meet his expectations for the quality of the printed image. On one of the folios bearing anatomical studies, produced around 1510, Leonardo noted:

> As regards this benefit I give to posterity, I show the method of printing it in order, and I beseech you who come after me not to let avarice constrain you to make the prints in … [missing]. (Royal Library, Windsor. Inv.: RCIN 919007)

Because a bit of paper is missing at the lower edge of the folio, the last word of the sentence, of all things, is lost. Experts agree, however, that it must have been *legno*, the Italian word for wood. If that is indeed the case, then this passage expresses Leonardo's disregard for woodcut printing and advises posterity not to use the technique to reproduce his anatomical drawings in print.

How else could Leonardo's work be printed "in order" at the time? The palpable alternative to woodcut would have been engraving. In contrast to woodcut, which is a relief technique, engraving is an intaglio technique, meaning the carved area is printed. The design is cut into a surface, usually a copper plate with a sharp pointed metal tool. The incised lines hold the ink and leave the impression when the image is printed.

Engraving grew out of the goldsmith's art. Like woodcut, it was already being used as a printing technique before the onset of printing books with moveable type. Engraving was enthusiastically adopted by Italian painters in the second half of the 15th century. It has even been claimed that an engraving produced in 1505 by Marcantonio Raimondi depicts Leonardo. Without a doubt, Leonardo was aware of engraving as a printing technique. However, when he wrote his note in 1510 it would hardly have been necessary to "show the method" of engraving to anyone as the technique was extremely familiar to anyone involved in book printing. What other method of printing images could Leonardo have been referencing?

When Leonardo wrote his short entry, another intaglio technique was just becoming available—etching. An acid-resistant material, such as wax, is applied to a metal plate. Then, a needle is used to scratch the design into the wax, leaving the metal exposed along the lines. The plate is then dipped into an acid bath. The acid etches away the metal in the free areas whereby the length of the exposure to the acid determines the depth of the lines and consequently how strong they will be printed. Etching, which had been used since the Middle Ages by metal workers to put decorative patterns on metal items such as pieces of armor, was supposedly first applied to printmaking around 1500 in Germany.

Etchings are much quicker to produce, and scratching into wax is much closer to the artist's craft of drawing with pen than engraving a metal plate is. However, with regard to the printing of illustrated books, etching also had its disadvantages. Movable type and etching, the former being relief and the latter intaglio, cannot be printed together in one operation of the press. The text had to be printed first, and the illustrations were added to the designated spaces left blank in a second run. Moreover, etching must be printed under much higher pressure than is required for text, necessitating the use of a second, different type press, a roller press. The etching press leaves a characteristic indentation from the plate's edges in the paper.

The earliest known etching that can be confidently dated was made and printed in 1513 by Urs Graf, a Swiss goldsmith. Around the same time, Dürer famously experimented with etching, but soon returned to engraving. Etching was first used for printing in Italy around 1520, only after Leonardo’s death. It is hence exceedingly unlikely that Leonardo is referring to etching when he talks about “the method of printing” he wants to show to others. What possibly remains?

The likely answer is provided by an entry in another manuscript. On fol. 119r of the *Codex Madrid II*, under the heading “Of how to cast this work in print,” Leonardo writes:

> Coat the iron plate with white lead and eggs, and then write on it left handed, scratching the ground. This done, you shall cover everything with a coat of varnish … . Once dry, leave the plate to soak; the ground of the letters … will be removed … leaving the letters adhering to the copper plate. After this, hollow out the ground in your own way, and the letters will stay in relief on a low ground.

The procedure proposed in this paragraph by Leonardo compares in its first step to etching. An iron plate is coated with a mix of eggs and white lead, the latter serving as white pigment. Then the mirrored (what Leonardo refers to as “left-handed”) design or text are scratched into this coating, leaving the metal bare. Because the coating is white, the lines will stand out clearly on the dark plate.

The next step, however, departs from standard etching. The exposed parts are stopped out with a varnish. The varnish acts as a permanent coating that will not wash off or be attacked by acid. Soaking the plate in water will remove the egg coating but not the actual design or text. In a last step, the ground is removed (in other words, the parts of the plate not covered in varnish must be hollowed out). Leonardo was not aware of etching as a printing technique, but he was certainly familiar with metal etching, and there can be no doubt that this is the method by which he intends to remove the ground.

The method Leonardo proposes in this passage clearly produces a metal relief print or a relief etching, as it may be called, that would have allowed his designs to be printed together with text in one operation with letterpress. We have no indication as to whether Leonardo only contemplated the idea or actually put it to practice, becoming his own printer. Metal relief etchings were first printed in the early 19th century. The plates for the prints were prepared according to what has become known as the *procédé Comte*. Except for the different materials used, the process is effectively the same that Leonardo had already proposed some 300 years earlier.

Fig. 3. Nature print of a sage leaf. Leonardo da Vinci. ca. 1478–1518. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 197v (detail). Reprint: 1973–1975. Il Codice Atlantico Vol. 3. Florence: Giunti

On at least one occasion Leonardo acted as his own printer, albeit not quite in the way one might expect. Folio 197v of Leonardo da Vinci's Codex Atlanticus bears a curious depiction of a sage leaf (Fig. 3). The appearance is strikingly different from Leonardo’s other sketches, the ink is noticeably darker, and even though the outline and the ramifications are very detailed, there are some unexpected gaps in the leaf veins, and the ink seems to have run in unusual manner in some places. Upon closer inspection, one realizes that this image is not a drawing at all, but a printed impression of the leaf

Fig. 3. Nature print of a sage leaf. Leonardo da Vinci. ca. 1478–1518. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 197v (detail). Reprint: 1973–1975. Il Codice Atlantico Vol. 3. Florence: Giunti

Image:
05_Buettner_03

Earlier examples of such nature prints, as they later came to be called, are known. Yet, Leonardo is clearly less focused on reproducing the leaf; rather he is interested in the print process itself, as a short accompanying paragraph shows. In it, Leonardo describes an alternative way to print the sage leaf, this time white on black, so that the "concavities appear shaded and the reliefs illuminated." In order to achieve this effect, first blacken a sheet of paper with the soot of a candle mixed with glue and then apply white lead, a naturally appearing white pigment, to the leaf "as you do to letters in printing." Then print in "the common way," that is, in the manner in which thousands of pages were printed every day in the print shops all over Europe.

More than a century passed before the first of Leonardo's works was handed over to these prolific presses. After Leonardo died in 1519, his last disciple and assistant Francesco Melzi, who inherited all of Leonardo's writings, oversaw the heritage of his master. With the help of collaborators, he began a thematic compilation of Leonardo's notes regarding painting (Life and Legacy D □). The project was never finished, but an abridged version of the text compiled by Melzi started to circulate under the title *Trattato della Pittura*. It was published in 1651 in Paris by Raphael du Fresne in Italian as well as in French (Life and Legacy F □). Without access to the original manuscripts and deceived by the authority of print, most of its early modern readers mistook the book for a genuine work by Leonardo.

Today, the situation has dramatically changed; every known surviving line Leonardo ever penned is available in print. For every page that Leonardo wrote upon, there are hundreds of books and articles about him and his work. Indeed, a WorldCat search (the world's most comprehensive database of library materials) for titles including "Leonardo" yields almost half a million results. This astounding number directs our attention to one of the more troublesome consequences of the print revolution, which had already begun in Leonardo's day. It has flooded us with information printed on paper, which permanently threatens to disorient and drown us.

Currently, we are in the midst of a new information revolution. The Gutenberg galaxy is being superseded by the digital age. Just as Leonardo was a child of the printing revolution, we are children of the digital revolution. More information is being made available each and every day than ever before. However, the computer is also giving us new means of organizing, connecting, and representing our information. These resources are just as important for the preservation of cultural heritage as they are for recording new information. Leonardo's work is continually becoming available in new and exceptional ways. On the occasion of the 500th anniversary of Leonardo's death, for instance, the Biblioteca Comunale Leonardiana di Vinci debuted the digital platform e-Leo, which presents Leonardo's manuscripts and links them to each other and to essential external sources. The digital format allows material to be represented in way that enriches the associative and networked character of Leonardo’s records that the linear form of print has not achieved. It is easy to imagine that Leonardo would have enjoyed the possibilities of these formats. We can only recommend that our readers enter the digital arena to meet Leonardo afresh.

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The Unfinished Museum: Leonardo da Vinci's Work from the Perspective of a Modern Technical Collection in the Deutsches Technikmuseum

Dan Reynolds, Kerstin Wallbach, Nikolaus Weichselbaumer

The collections and exhibitions of the Deutsches Technikmuseum (German Museum of Technology), founded in 1982, presently include over 150,000 objects in an area larger than 26,500 m^2 and consisting of exhibition spaces, the archive, the library, depots, and workshops. Its collections mainly focus on the 19th and 20th century.

Around 1980 the first planning concepts were developed for the new museum, which was based on earlier collections. The emphasis was on the elementary relationships of technology to nature, culture, history, and the future. The plans also emphasized the possibility of visitor access to "unrestored objects that had not yet been prepared for educational purposes," and for visitor participation in "establishing multiple yawning gaps." A few years later, in 1985, the founding team gave this idea a name: "Making the unfinished a principle."

Given the multiple challenges and often meagre resources, today's considerations on the future of museums and new ways of accessing collections, libraries, and archives are happening once again as an ongoing process, and have to maintain a large degree of openness to be able to function at all. Perhaps the question of a view of Leonardo da Vinci's works from the perspective of a large modern technological collection is connected with the aforementioned question from the 1980s of "empty spaces at the intersection of technology, nature and art"—spaces that are just as important in collections as, for example, non-printing materials in hand printing.

This essay focuses on the collection "Printing and Papermaking." The materials involved require particular and constant care to conserve stocks. Most of the materials come from large printing industry enterprises that once had or still have their main offices in Berlin. Besides many smaller businesses, they included, for example, the typefoundry and factory for machined brass printer's rules H. Berthold AG, the Federal Printing Office and its predecessors, Druckhaus-Mitte (formerly Mosse), Rotaprint, and the printing office of the Deutsche Reichsbahn (German Railways). The latter played a major role as a transport company with a state monopoly in the general field of rail traffic. Its permanent exhibition includes a section on the Reichsbahn's involvement in the Holocaust. In the prewar period, the Deutsche Reichsbahn was Germany's biggest employer, with over 700,000 workers.

Printing collections today rarely contain complete printing offices. Instead, the preserved, now "unfinished" parts are used in a new way. There are important object groups that are not very often represented in collections, were never collected or not included on account of heavy transport and storage costs, unless they already belonged to the stock in the building. Printing presses, paper machines, ladles or type could continue in use as essential parts of the production process. Printing stones for lithography and type cases acquired new importance as building materials or decoration.

Museums in the 21st century no longer have to own everything, but most importantly they have to open up access to their archives and collections and help in understanding multiple processes. Many objects already carried a future inside them.

Leonardo's Sketch of an Improved Printing Press

The unfinished is clearly present in da Vinci's work. His collections of sketches show a variety of untested and half-baked ideas. The idea of an "unfinished" museum can benefit in many respects from looking at the work of Leonardo da Vinci.

Letterpress printing with multiple and movable type was invented in the time around Leonardo da Vinci's birth. By the time of his death in 1519, it had changed the world fundamentally. Leonardo himself only used letterpress printing once in his own work, in his graphical contribution for Luca Pacioli's *Divina Proportione* (75 □). The rest of Leonardo's works were all printed after his death. But two sketches from the *Codex Atlanticus* show us that he certainly examined the topic of printing intensively as an engineer and not only understood the construction of printing presses but also sketched a proposal for improving their efficiency (13 □) (Fig. 1).

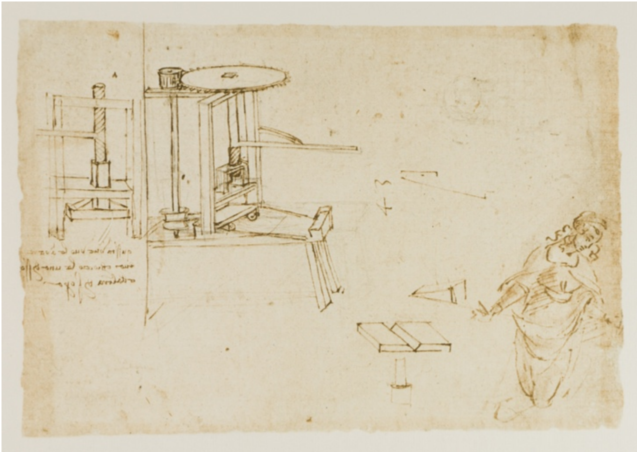

Fig. 1. Leonardo da Vinci. ca. 1480. *Sketch of an improved printing press*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 995r (13 □), reprint: 1973–1975. Il Codice Atlantico Vol. 11. Florence: Giunti

Fig. 1. Leonardo da Vinci. ca. 1480. *Sketch of an improved printing press*. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 995r (13 □), reprint: 1973–1975. Il Codice Atlantico Vol. 11. Florence: Giunti

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Wooden printing presses were usually operated by two printers. One was responsible for removing the printed sheet and laying down a new one, while the other inked the printing forme and completed the actual printing by pulling the bar. In the work process of book production, printing was the only step that required two people. Punchcutting, typecasting, composition and corrections could each be done by just one person.

Leonardo's sketch shows a design intended to improve the efficiency of the printing press. The spindle of the press is connected through two gears with a high transmission ratio to a shaft with a roller at the bottom end. This roller is connected by ropes to the carriage of the press. With this mechanism, when the bar is pulled, first the carriage is drawn under the platen of the press and then the sheet is printed. The process results in several constructional and systematic problems. The fact that the material dimensions of the construction are disproportionately small should not distract us – this actually makes the sketch much clearer and more legible. But the manufacture and calibration of the exact timing of the roller mechanism would have been complicated. Ultimately the platen has to be at the right place in exactly the right moment. The sketch does not show whether the carriage is wheeled out again under the press after the printing is done, but it is quite possible to imagine a rope running in the other direction.

The major design problem for Leonardo's improved press was posed by the materials available to him. With the materials and technologies of the early modern era, it was difficult to build bearings for the shaft and carriage that would have reduced the friction of the mechanism to a degree that did not hamper the printing process. Even with a conventional press, it is sometimes necessary to pull the bar two or three times to create enough pressure. It was not until the iron press that emerged around 1800 that printing with just one cranking became possible. And even if all that could have been resolved, it is very likely that a printing office equipped with Leonardo's improved press would have deployed two printers at the press. The bulk of a printer's work consisted of removing and placing the sheets. Moving the carriage was a minor part compared with this. In practice, by the early 16th century at the latest, the transportation of the carriage had been replaced by a crank handle that could be used independently of the actual printing process. It is not known whether a press in the style of Leonardo's was ever built for use in production. All the same, this drawing is remarkable because it shows that Leonardo, who did not use letterpress printing as a medium himself, studied it so intensively as an engineer that he was able to sketch an improvement that was far ahead of his time in terms of ideas about automation.

Da Vinci's sketch envisaged the labor involved reduced from two people to one printer. In fact, in the following centuries the division of labor in printing became increasingly specialized, often with smaller and more narrowly defined fields of work. The industrialization of printing was characterized, however, not only by high-speed presses, steam-powered rotary presses, and continuous rolls of paper but also by the development of smaller one-person machines like the Liberty press or the later jobbing press that actually incorporated aspects of da Vinci's ideas. The desire to accelerate the speed of printing, the Western "invention" of printing associated with Gutenberg, can be seen generally as the acceleration of the production time of books, at least compared with the copying workshops that were still widespread, where texts were copied by hand. The number of printed pages that even small printing offices could produce in a day rose rapidly during the 19th century. In the mid-20th century relief printing was completely replaced by a different technology – offset printing. If this had not happened, manufacturers of printing presses like Heidelberger Druckmaschinen AG, which manufactured a common windmill press, would probably still be working on refining their processes.

Garamond, Bodoni, Bodoni Old Face

Although the underlying technology changed very little over 500 years, there was one aspect of movable metal type that was being constantly improved: the design of the typefaces themselves. These underwent a continual transformation that has even survived the era of letterpress printing. The best-known examples are probably the multiple adaptations of fonts by Claude Garamond (died 1561), whose lifetime overlapped with that of Leonardo da Vinci.

In the printing offices of Leonardo's time, an established division of labor already extended past the operation of the printing presses themselves. Another category of worker was responsible for typesetting; these people composed the texts that would appear on the printed pages, but they probably were only rarely responsible for the actual printing themselves.

Typesetting was the last of all the domains of letterpress printing to be mechanized. Even in the 1880s, when typesetting machines like those from Linotype and Monotype were introduced, many printed works were still typeset by hand. Typesetters from the late 15th century could have easily found their way around and simply carried on with their work in the last commercially operated composing rooms of the 20th century, and even until the time the Deutsches Technikmuseum opened. Technologically speaking, little had changed for a long time since Leonardo’s death.

The oldest exhibits in the type and print collections of the Deutsches Technikmuseum are punches (patrices) for production of typographic matrices at the Königlich Preußische Geheime Ober-Hofbuchdruckerei (Royal Prussian Privy Court Printing Office) owned by the Decker family from the 18th century, later the Reichsdruckerei (Imperial Printing Office) and now the Bundesdruckerei (Federal Printing Office).

Much older objects from the 16th century—and possibly even from the 15th—are preserved at the Plantin-Moretus Museum in Antwerp, which derives from the printing office that Christoffel Plantin (died 1589) established. The Plantin-Moretus Museum is a UNESCO Cultural Heritage site. It includes original tools and materials for type production by famous punch-cutters like Claude Garamond from Paris. With the aid of hand casting instruments, movable metal type can be made there today using original matrices and printed on both historical and more modern letterpress printing presses. Besides preservation and conservation, an important task of printing collections in museums is to enable further usage both for research and for educational and artistic purposes.

Fig. 2. Six different interpretations of Giambattista Bodoni’s typefaces used for photo-typesetting ca. 1980. Although little changed in technical terms over five centuries, there was one area in the production of movable type in which the constant attempts to improve results could be very clearly felt: the design of the actual characters. There was continual evolution in this regard, a feature that even survived the age of letterpress printing. Gerstner, Karl. 1984. *IBM Bodoni Manual*. Part 1: *The Right Choice*. Armonk, NY: IBM, 16–17

Typefaces by Garamond were valued for their appearance in his lifetime and beyond. At least since the early 20th century, printers and typographers have regarded them as the ideal representation of the typographic image of the French Renaissance. In just a few years between around 1910 and the end of the 1920s, many new fonts derived from Garamond’s 16th-century designs were brought onto the market. They included fonts for hand composition from the American Type Founders Company in the USA, for the Monotype composing machine in Britain and for Linotype-setting, which in Germany were made by D. Stempel AG in Frankfurt am Main. Since then, typeface designers have continually reinterpreted these types and adapted them for new compositional techniques. Several firms have even produced multiple interpretations of Garamond’s types for the same kind of composition technology. For instance, D. Stempel AG produced Garamond-style typefaces for hand-composition and the Linotype in 1925 and 1967, while Adobe Systems released separate interpretations for digital typesetting in 1989 and 2005.

The work of the punch-cutter and printer Giambattista Bodoni (1740–1813) in Parma is a similar example (Fig. 2). As was the case with Garamond, many 20th-century typefoundries and typesetting-machine manufacturers published products reinterpreting Bodoni's letterforms in a new way. Just as Garamond's typefaces embodied the French Renaissance for printers and typographers in the 20th century, Bodoni's typefaces and books were seen as the embodiment of European Neoclassicism.

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Image:
06_Wallbach_Museum_02

At the end of the 1920s, the Berlin-based typefoundry and brass-rule manufacturer H. Berthold AG started selling Products based on Bodoni's oeuvre. Berthold continued to operate past the letterpress era and manufactured photo-typesetting machines for use in offset printing during the second half of the 20th century. New fonts for these photo-typesetting machines were required for both technical and design reasons. Berthold also produced these in-house. The greatest number were made under the firm's supervision by its artistic director Günter Gerhard Lange (1921–2008), including an adaptation of the aforementioned lead type version of Bodoni that Lange had reworked in the 1970s. Known as the "Berthold Bodoni," it came onto the market at around the same time as several other new interpretations for the photo-typesetting era. At that time the multinational concern IBM used many of these Bodoni adaptations in its printed matter, as they had been developed independently they all looked slightly different. The Swiss typographer Karl Gerstner (1930–2017) was commissioned to standardize typefaces used in company publications. In Gerstner's opinion, the Berthold Bodoni was the optimal Bodoni interpretation for photo-typesetting. In the mid-1980s it became the IBM house font. Lange's fascination with Bodoni's types continued; in 1983, he introduced another "revival," Bodoni Old Face.

Punchcutters like Garamond and Bodoni created not just one, but several typefaces during their careers. Bodoni himself created over 100 different ones. Each revival used different typefaces as a model. The Berthold Bodoni was a photo-typesetting interpretation of a Bodoni revival interpretation for lead type composition dating back to the 1920s. Bodoni Old Face had fewer interim steps. Lange based his font on the look of letterforms from a single original print by Giambattista Bodoni himself.

The Berthold Bodoni and Bodoni Old Face were not the only instances of Lange reinterpreting a specific printing genre several times. As mentioned above, it was typical in the typefounding trade to reproduce new products based on the same model again and again.

Lange's multiple additions to and new interpretations of the Akzidenz-Grotesk typeface were used even more often in the printing industry than his Bodoni fonts. Akzidenz-Grotesk, a sans-serif typeface, was introduced into the Berthold product range in the 1890s (Fig. 3). In the late 1950s and the 1960s, Lange designed new metal type extensions of the Akzidenz-Grotesk “typeface family.” He later adapted the family for photo-typesetting three different times under the product names Akzidenz-Grotesk, AG Buch, and AG Old Face. In the two decades before his death, Lange collaborated on further interpretations for digital typography including Akzidenz-Grotesk Pro and AG Royal. At the end of his life, he probably regarded the Akzidenz-Grotesk design as still being unfinished, at least in terms of how it could be used in the new medium of digital typesetting.

Fig. 3. Photo-typesetting matrix, Akzidenz-Grotesk. Since the early 1980s, type designers around the world have produced several other digital versions of Akzidenz-Grotesk under their own product names to avoid trademark issues. Printers and typographers appreciate these products and are well able to spot their similarities to the “original” font. SDTB / Photo: C. Kirchner

Image:
06_Wallbach_Museum_03

Fig. 3. Photo-typesetting matrix, Akzidenz-Grotesk. Since the early 1980s, type designers around the world have produced several other digital versions of Akzidenz-Grotesk under their own product names to avoid trademark issues. Printers and typographers appreciate these products and are well able to spot their similarities to the “original” font. SDTB / Photo: C. Kirchner

Nature as Printer

Among the legacies conserved by the Historical Archive of the Deutsches Technikmuseum are the estates of Günter Gerhard Lange and H. Berthold AG. They are important for understanding the collection as a whole because they document the transition from hand typesetting to digital composition, offering indispensable insights into the ideas and actions of the actors of that period. In dealing with them it seems important to start from the idea of not “freezing” the stocks but giving adequate space to the process itself, the gaps involved, and the overlapping of different phases of design that are integral to the construction of fonts.

In 2019 the new version of the permanent exhibition on typeface and printing technology in the German Museum of Technology was expanded by a small section called “Nature as a Printer,” (Fig. 4), a thematic introduction to a new exhibition and workshop field. It is possibly the only spot in the whole museum where the name Leonardo da Vinci is consistently mentioned, in relation to the nature prints he made himself. It shows tactile replicated leaves and a bat’s wing that can be seen with the aid of a special layered printing process. The section also serves as an introduction to the area dealing with the printing of images, which begins with an exhibitable lithography workshop once owned by the master lithographer and offset printer who was probably the last of his kind to operate commercially in Berlin.

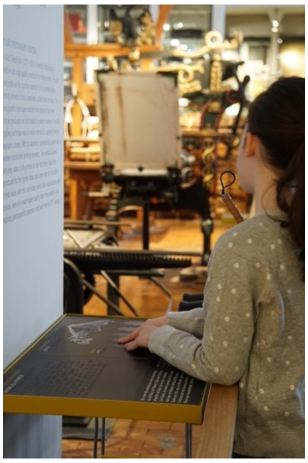

Fig. 4. Blind woman visiting the station “Nature as Printer.” A Columbia cast-iron printing press from 1835 can be seen in the background and a reconstruction made by the museum of a wooden press from the 17th century as a replica of a press from the Plantin-Moretus Museum from 1986. SDTB / Photo: Steffi Hengst

Fig. 4. Blind woman visiting the station “Nature as Printer.” A Columbia cast-iron printing press from 1835 can be seen in the background and a reconstruction made by the museum of a wooden press from the 17th century as a replica of a press from the Plantin-Moretus Museum from 1986. SDTB / Photo: Steffi Hengst

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The desire for the most accurate possible illustrations from nature, like the plant collection in a herbarium, is much older than the technical preconditions for reproductions with printing technology. The imprint of a sage leaf in the *Codex Atlanticus* with handwritten notes on the production and use of paints is an early example of a homemade nature print (CR Büttner Fig. 3). Da Vinci was presumably interested in visually supplementing his nature studies by making the very fine branching and structures visible. Two main forms are distinguished in self-made nature prints: first, the use of plants and other objects from nature such as insect wings, bird feathers, or flat fossils as a print form of their own (*typographia naturalis*; physiotypography); second, the transfer to more durable print forms, often by multi-stage processes. In the case of many rare applications in the 18th–19th centuries, such as the use of original wooden discs for manufacturing wood wallpaper, it is difficult to reconstruct the techniques used; for later photomechanical reproduction it is nearly impossible.

Self-made natural prints using original objects as print forms made use of processes that were very similar to those for book printing or high-speed printing. The fragility of the print forms meant that only a few imprints were possible. From today’s perspective we are not talking about prints in the sense of an intentional reproduction of templates as it was later defined in various DIN standards. In fact, we mean the production of unique specimens just like drawings or paintings.

By contrast, adaptations to more durable print forms, for example through lithographical transfer printing and overprinting processes or galvanic techniques, enabled, above all, much larger print runs of books. In particular, the colored prints produced by chromolithography display exceptionally rich detail, were valuable from a scientific perspective and still outclassed the possibilities of photography until the 20th century.

The second aspect of the section “Nature as a Printer” is to provide access to an exhibitable lithographical workshop which was acquired in its entirely in 2016. It is one of many completely or partly preserved workshops belonging to the museum that was closely connected with specific places and often operated over several generations. Their former owners had a store of precious knowledge and experience which they often carefully documented. Some important remarks by the master lithographer and offset printer Dietmar Liebsch, from whom the Deutsches Technikmuseum acquired the workshop, have been recorded on film in recent years. They include the following:

> In lithography, there is an emotional aspect to the connection with the print form. Limestone [as a print form] is millions of years old and it asks questions, it remembers.
>
> In the case of artistic lithographs feelings like insecurity or fear in relation to the print form directly affect the result, and consequently the work of art itself.
>
> Handling original printing plates, such as those of Adolf Menzel (in the stocks of the Stadtmuseum Berlin), which can still be used for making prints after 150 years,

> requires great care, along with a sense of confidence gained through many years of work, to prevent something being irrevocably lost.
>
> When reactivating motifs that occur in the surface of the stone in the µ-field it is imperative that nothing is altered or retouched. Even things that seem wrong to us today have to be consciously taken on board.

Liebsch was over 70 years old when he first began developing his own motifs instead of exclusively doing reproduction work for clients. He chose an abstract experimental approach based on complex knowledge gained from experience and specialist wisdom, which could only be realized by printing technology, not by drawing or painting. The few works of this kind he produced are remarkable for their openness. They allow space for what is accidental, leaving the viewers completely free to decide what they think they are seeing.

Leonardo da Vinci developed, changed, and documented a variety of artistic and scientific techniques, processes, and constructions. Even today his works touch on important questions in nearly all fields of work in museums, archives, libraries, universities, offices, and many other places at the intersection of crafts, art, industry, science, and design.

Da Vinci's sketches and drawings anticipate moments of the photocopy, of Polaroid photos. They evolve forms from movements, such as when they are used as the basis for typographical design processes. The unfinished museum is a great opportunity.

Translated from the German by Karen Margolis

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Of Visible and Invisible—Sometimes Only Imagined—Things

Luca Lombardi

The almost unlimited intellectual cosmos of Leonardo could not exclude music. Since he lived out most of his life during the second half of the 15th century, it was the music of that period that he was most familiar with—particularly given that in terms of music, nothing of much note occurred at the beginning of the 16th century—the world was yet to see Giovanni Pierluigi da Palestrina, who was not born until a few years after Leonardo's death, and who is considered one of the most prominent composers of the European Renaissance.

Fig. 1: Leonardo da Vinci, *Portrait of a Musician*, (identified by some art historians as Josquin Desprez), ca. 1485, Milan, Pinacoteca Ambrosiana. akg-images / De Agostini / A. Dagli Orti

One of the most notable composers active in the 15th century was Guillaume Dufay (1397–1474). It is very likely that Leonardo knew his *Missa L'homme armé* (the armed man). It may be pure coincidence that the notes and intervals written by Leonardo as a musical commentary on his statement that music is "la figurazione delle cose invisibili" (the description of invisible things) on a five-line system bear a close resemblance to the beginning of the song "The Armed Man" on which Dufay's famous mass is based.

Another prominent composer was Johannes Ockeghem (died 1497), who was also, incidentally—like many other composers of that time —author of a mass based on the song of the "armed man" (Fig. 1).

Fig. 1: Leonardo da Vinci, *Portrait of a Musician*, (identified by some art historians as Josquin Desprez), ca. 1485, Milan, Pinacoteca Ambrosiana. akg-images / De Agostini / A. Dagli Orti

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Leonardo himself composed music, although his musical creations of a popular character bore no comparison to his genial creations in other fields. It seems as if composing is a very demanding mistress who does not tolerate other mistresses. The same is true of other distinguished personalities (admittedly not as distinguished as the incommensurable Leonardo), who also composed, but did not produce anything of substantial note (see Adorno, or Ezra Pound, or Friedrich Nietzsche).

Leonardo was, however, an ingenious inventor of musical instruments. He lived through a time known for the invention and construction of many new musical instruments. Some of the instruments we take for granted as mainstays of music, such as the violin, simply did not exist in his time. It was not until the mid-16th century that Andrea Amati, teacher to Antonio Stradivari, created the first violin in Cremona. A glorious time in which many things were invented, imagined, built and dreamed, on which we still feast today. A Polish musician recreated such an instrument, the "viola organista," which seeks to combine the possibilities of a keyboard and a string instrument (Fig. 2).

Fig. 2: Sławomir Zubrzycki playing the “viola organista” invented by Leonardo. © Sławomir Zubrzycki / Photo: Klaudyna Schubert

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07_Lombardi_Dingen_02

Fig. 2: Sławomir Zubrzycki playing the “viola organista” invented by Leonardo. © Sławomir Zubrzycki / Photo: Klaudyna Schubert

I could well imagine a concert performed on recreations of instruments invented by Leonardo. Music inspired by the spirit of the Renaissance, anchored in the present, projecting into the future. Because Leonardo is a man of the past, the present, and the future, all at the same time.

With that in mind, I am currently thinking about a composition that aims to be a sonorous encounter between Master Leonardo and Master Josquin Desprez. They will meet on the occasion of this exhibition dedicated to Leonardo, organised by the Max Planck Institute for the History of Science in Berlin. What will they say to one another? I wonder ... . Perhaps they won’t talk about music and musical instruments at all, or even about Leonardo’s paintings or his inventions; perhaps they’ll talk about the hope he once expressed in these words: “Fin dalla più tenera età, ho rifiutato di mangiar carne e verrà il giorno in cui uomini come me guarderanno all’uccisione degli animali nello stesso modo in cui oggi si guarda all’uccisione degli uomini” (From an early age, I refused to eat meat, and the day will come when people like me will look at the killing of animals in the same way as the killing of people today). Leonardo, brother, that day will come—but how much longer must we wait for it? How much longer will it be before the “armed man” stops waging war on his own kind and on other animals, indeed on the whole of nature, of which he is a part?!

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Disruptive Measures: Leonardo's Vitruvian Man and the Squaring of the Circle

Horst Bredekamp

If there is one icon that seems to define the ideal image of human appearance, it is the drawing created by Leonardo da Vinci in 1490 with metalpoint and ink on white paper at the Accademia in Venice (Fig. 1). It shows a man without clothing holding his arms out horizontally to touch a square, while his outward angled legs as well as a pair of arms that are angled slightly upward touch a circle. The face, framed by locks of hair, gazes forward unwaveringly. It is as striking as the athletically rendered body.

Fig. 1. Leonardo da Vinci. *The Vitruvian Man*, drawing after Vitruvius, *De architectura* III. 1, ca. 1492. Pen and brown ink with traces of wash over metal stylus. Gallerie dell'Accademia, Venice. Inv.: 228 (40 □). akg-images

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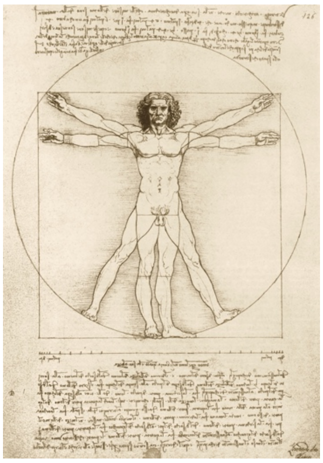

Fig. 1. Leonardo da Vinci. *The Vitruvian Man*, drawing after Vitruvius, *De architectura* III. 1, ca. 1492. Pen and brown ink with traces of wash over metal stylus. Gallerie dell'Accademia, Venice. Inv.: 228 (40 □). akg-images

The idea of inscribing the body in a square and a circle dates to Vitruvius (31 □), who served as a military engineer under Caesar and Augustus. In the third volume of his work on architecture, he presented a section on the proportions of the human body, whose center he defined as the navel. According to Vitruvius, a person laying on their back with arms and legs outstretched will touch a circle as well as a square with a common middle point at the person's navel. This statement was all the more suggestive because in other texts, Vitruvius pursues the geometric idealization of humans down to the finger joints, based on the famed Canon by the Greek sculptor Polykleitos.

The lines that Leonardo draws at the knees and the genitals, as well as the nipples, base of the arms, elbows, eyebrows, and base of the nose all follow these specifications. By drafting body parts by proportionality based on numbers and geometry, Leonardo's Vitruvian Man became the model of success for all design. A sort of theory of everything arose from the *convenevolezza* of this interplay between the body and geometry. The notion, valid in cosmology as well as particle physics, the microcosms and macrocosm correspond because the laws of the universe can be discovered in the smallest particles, was metaphorically linked to this figure.

All of these considerations are based on the assumption that Leonardo's Vitruvian Man was envisioned as an ideal model. But this conclusion misinterprets and underestimates the Vitruvian Man. It does not show the coincidence of human proportion, square, and circle, but rather the difficulty of making them coincide. Leonardo's drawing proves Vitruvius's indications to be an illusion, if not nonsense. After a series of studies, Leonardo recognized that Vitruvius's proportional figure could not be realized. In order to form a circle, he bent the arms of his Vitruvian Man slightly upward and widened his stance accordingly. The square, in contrast, is formed by the straight legs and horizontal arms. The man is inscribed in a circle and a square, but it has two centers: the navel is the center of the circle, while the genitals are at the center of the square. The ingenuity of the drawing lies not in the implementation of Vitruvius's idea, but rather its correction of it. Maybe that is why the man, who is an adult with the body of a youth, looks so grim.

Fig. 2. Carlo Urbino, *Undezima figura*, ca. 1560–1570, pen-and-ink drawing. *Codex Huygens*, Morgan Library & Museum, New York, fol. 29. © Morgan Library & Museum, New York

It is no longer possible to know whether Leonardo saw his Vitruvian Man as a vector of motion from the beginning, or whether he was first stimulated by the problem of his drawing to an understanding of the human body that leads from stasis to motion. In any case, the circle and square can only be related in sequence, and for this reason, Leonardo's model figure is not a simultaneous shot, but rather a compressed film. The human body cannot be frozen in proportions; it must be understood in motion, as a machine that is always moving. As the anti-Vitruvian Man, Leonardo's model drawing is the snapshot of a great cinema that includes all forms of this engine's motions, and all of life along with it. It falls in line with a sequence that an unknown student of Leonardo's handed down in the *Codex Huygens* (Fig. 2). In numerous model panels, the human body's possibilities of motion are captured using dotted lines. As the accompanying text explains, these lines are an abstracted form of a diagram of the heavens because "the bones and nerves follow the movements of the heavenly bodies, according to our first order. And so this extended body is depicted over its natural background, our great mother, out of which we rise and into which we return." Humans and the cosmos are intertwined, but motions cannot be forced into a square and a circle. Rather, they follow geometries that are in a constant state of metamorphosis. The Vitruvian Man is the snapshot of a sequence of motion that should not be understood as a static ideal, but rather as a moving film.

Fig. 2. Carlo Urbino, *Undezima figura*, ca. 1560–1570, pen-and-ink drawing. *Codex Huygens*, Morgan Library & Museum, New York, fol. 29. © Morgan Library & Museum, New York

Image:
08_Bredekamp_Vitruvmann_02

During his second journey to Italy from 1505 to 1507, Albrecht Dürer undertook studies of proportion that apparently included Leonardo's considerations (Fig. 3). The studies were first published in Nuremberg after his death in 1528 under the title "Herein are comprised four books of human proportion" (93 □). Dürer must have clearly understood the problem that the square could not be centered around the navel because in all

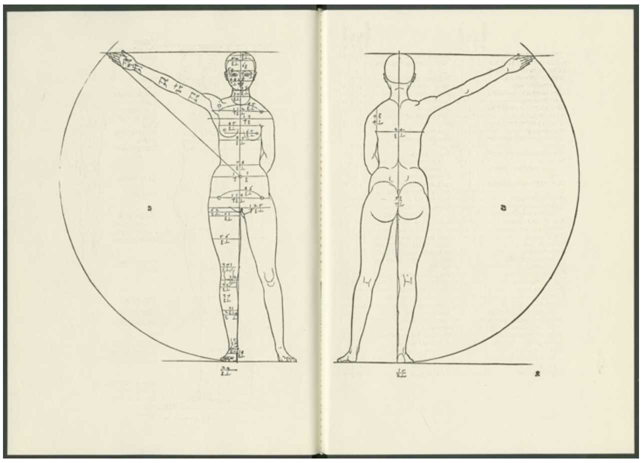

Fig. 3. Albrecht Dürer, Female Proportion Studies, 1528, from: *Hierin sind begriffen vier Bücher von menschlicher Proportion* …, Nuremberg 1528, sheet k1r–k1v (93 □). Reprint: 1996. Nördlingen: Uhl. Max Planck Institute for the History of Science, Berlin. Shelfmark: Sou II D853h

of his drawings, he only uses the circle to delimit the extremities. He claimed to have "measured" two to three hundred men and women, which does not mean that he took their bodily measurements, but rather that he represented them individually as precisely sketched, mathematically and geometrically defined figures.

Fig. 3. Albrecht Dürer, Female Proportion Studies, 1528, from: *Hierin sind begriffen vier Bücher von menschlicher Proportion …*, Nuremberg 1528, sheet k1r–k1v (93 □). Reprint: 1996. Nördlingen: Uhl. Max Planck Institute for the History of Science, Berlin. Shelfmark: Sou II D853h

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In more recent times, these sorts of measurements were considered the definition of ideal measurements, with consequences for the normalization of exemplary bodies and the supposed elevated status of certain ethnicities. But diversity can only be demonstrated and constant metamorphoses assessed if measurements are taken. Leonardo and Dürer did this in an exemplary fashion. Just as Leonardo demonstrated the impossibility of the Vitruvian ideal, Dürer did not discover a norm, but rather relative sizes that are inherently harmonious and in no way suggest that a binding standard should be set. By following Leonardo's example and seeking to record a large group of people proportionally in pursuit of the secret of beauty, normative measurement shatters in his hands. All of his investigations lead to this breathtaking pronouncement: "But as to what beauty is, that I do not know." Dürer acknowledged the uncertainty that defines all possibilities as harmonious in themselves but not as norms, confirming a relative conception of beauty that does not establish norms through measurements but rather proves the relativity of proportions.

Leonardo similarly criticized the "proportion calculators" (*proportionanti*) among the technicians because they were impervious to empirical evidence. His disruption of normative measurement aesthetics, which he displayed in successive simultaneous motions, drew on the work of Francesco di Giorgio Martini (66 □). This conversation partner and inspiration of Leonardo's managed to realize the teachings of Vitruvius with the nonchalance of an intuitive certainty that ideal measured proportions and reality will never coincide (Fig. 4). His Vitruvius figure turns inward in order to let one arm swing slightly outward, deviating from Vitruvius's prescriptions but making it more lifelike. It is a defense of the mobile proportionality that exists between the ideal proportional norm and the form that emerges in reality. Martini's definition of living measurements lies in a playful empowerment of general haziness, while Leonardo produced a second variant of the Vitruvius critique, one that is still effective today: the vital principle of cinematic metamorphosis.

Fig. 4. Francesco di Giorgio Martini, *Vitruvian Man,* drawing after Vitruvius, *De architectura* III.1, ca. 1475, Florence, Biblioteca Medicea Laurenziana, *MS Ashburnham 361*, fol. 5r (detail). Reprint: Marani. 1994. Trattato di architettura. Florence: Giunti

Fig. 4. Francesco di Giorgio Martini, *Vitruvian Man,* drawing after Vitruvius, *De architectura* III.1, ca. 1475, Florence, Biblioteca Medicea Laurenziana, *MS Ashburnham 361*, fol. 5r (detail). Reprint: Marani. 1994. Trattato di architettura. Florence: Giunti

Image:
08_Bredekamp_Vitruvmann_04

Translated from the German by Amanda DeMarco

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Anonymus (Francesco Mangano?): *Il Manganello*

Alessandro Nova

The two oldest manuscripts of *Il Manganello*, a work written in tercets in 13 chapters, date from the end of the 15th or beginning of the 16th century. The first manuscript, which was used as the basis for the modern edition of the work, is preserved in the Biblioteca Capitular y Colombina in Seville (Cod. 7.1.51). It was purchased in Ferrara in 1531 by Columbus's son, Hernán Colón, as attested by a note written in Colón's own hand. The second manuscript is part of a miscellaneous volume held by the Biblioteca Capitolare di Verona (MS CCCCLXXI (314) [fol. 129r–153r]) and perhaps reproduces the text of the only antique print, because it contains several minor errata typical of the transition from manuscript to print (Zancani 1995, 24–27). Two further manuscripts, which we can date between the 16th and 18th centuries, are found in Florence (Biblioteca Nazionale, Cod. II.IV.11) and Cambridge (Trinity College Library, MS R.3.28 [James 608]). The copy in the Biblioteca Palatina in Parma (PP.52) was lost in World War II, but dated from the 18th century.

The printed edition of *Il Manganello*, a small book of 28 folio pages, is even rarer than the manuscript version: the only copy catalogued in Italy, that of the National Library of Florence, has been lost. The only surviving copies to date are in the Bibliothèque Nationale in Paris (with the shelf mark Enfer 699) and owned privately. None of the copies give any indication of the date or place of publication, but Diego Zancani, the most authoritative scholar in the field, dates the work's composition, based on internal textual criteria, to the years between 1430 and 1440 or between 1430 and 1450, in other words half a century before it was printed.

Leonardo records the title "Manganello" in his two book lists (*Codex Atlanticus*, fol. 559r (3 □); *Codex Madrid II*, fol. 3r (4 □)). When Augusto Marinoni in his Lettura Vinciana *I codici di Madrid (8937 e 8936)* (published in Florence in 1975) disassembled and then reassembled Leonardo's library by genre, he included *Il Manganello* among works of an exclusively literary nature. But he kept his comments on the matter laconic:

> Rare little work in 13 chapters, printed twice in the 16th century by an anonymous man from Milan who says he was inspired by Giovenale (Satira VI) and [Boccaccio's] Corbaccio: a savage satire against women (and in favor of homosexuality) that seems to have led the Duchess of Ferrara to have the author executed.

A full century earlier, however, Girolamo d'Adda, the author of the first systematic study of Leonardo's library (*Leonardo da Vinci e la sua biblioteca*, Milan 1873), had offered a much richer and more nuanced interpretation, without resorting to the image of a merciless Duchess of Ferrara. According to his interpretation, *Il Manganello* would not have been the title of an untraceable book, but an allusion to the author's name—the surname Mangano comes to mind—likely of Milanese origin. Consider, for instance, how one fierce critique of the work—*La reprensione del Cornazano contra Manganello* (Cornazano against the reprehensible Manganello), discussed below—opened with the following two tercets:

> Reading your work in tercets, / Mangano, sometimes for amusement / that yes you struggle to refine with your file, / I am caught laughing, since Giovan Boccazzo / and the Satyr Juvenal Iunio d'Aquino / that you take as your leader in your beautiful Corbazzo. (Leggendo la tua opra in terza rima, / Mangano, alcuna volta per solazzo /

che sì ti sforzi polir con tua lima, / m'è piglià riso, ché Giovan Boccazzo / e ʾl satir Iuvenal Iunio dʾAquino / pigli per duce nel tuo bel Corbazzo.)

Relying in part on the research of Jacques-Charles Brunet, *Manuel du libraire et de l'amateur de livres,* Paris 1860–1880, D'Adda also noted the existence of two printed editions published shortly after each other, probably in the same Venetian printing house. The first, in octavo format, untitled and without a half-title page, had no indication of the date or place of publication. The 13 chapters of the text were preceded only by the words *Il Manga // nello* on two lines, and the unnumbered pages of the 28 folio pages were sorted by fascicles from A to D. D'Adda ultimately suspected that the work had been printed in the workshop of Nicolò d'Aristotle, called Zoppino, in the early 16th century or perhaps as early as the late 15th century.

This attribution to Zoppino was based on the work's characters that were used much later, by the same printer, for an edition of *La puttana errante* (*The Wandering Whore*) by Pietro Aretino. The second edition of *Il Manganello*, in sextodecimo format, which can be identified with the volume now catologued as Enfer 699 in the Bibliothèque Nationale in Paris, still contains 28 folio pages, but the characters in italics are said to have been be printed more roughly than in the first edition, of which every trace has been lost.

D'Adda's analysis does not end there, however: he continues by investigating the reception of the text (cited in *La reprensione del Cornazano contra Manganello*, in *Stanze in lode della Menta* by Luigi Tansillo, in the *Cicalamenti del Grappa* by Francesco Beccuti published in Mantua in 1545, and in works by other polygraphs), going so far as to suggest the existence of a third edition, which he thinks *must* have preceded the two mentioned above. He explains this conclusion by pointing to the content of the pamphlet *La reprensione del Cornazzano*, published without any indication of the author's first name and with the intention of refuting the misogynist theories of the pamphlet *Il Manganelllo*. The pamphlet was printed in octavo format by Bertoco, a publisher active in Ferrara toward the end of the 15th century.

Believing the author of *La reprensione* to have died in 1500, D'Adda identified him as Antonio, a complex character who moved between the courts of Milan and Ferrara as a poet, dance teacher, and military expert. This Antonio, however, had already died in 1484, and he was most likely not the author of this work. At the same time, it is quite possible that the printer appropriated his name in order to circulate a text that was deeply ideological in its criticism of *Il Manganello* and its praise of homosexuality.

In this context, it is worth recalling that Leonardo owned, or borrowed from Guglielmo de' Pazzi, a work by Cornazzano, namely the poem *Dell'arte militare*, printed posthumously in Venice by Cristoforo de' Pensi in 1493 and included in the list of books listed in the Second Madrid Codex (4 □). It is to D'Adda's credit that he drew attention to *La reprensione* in order to shed more light on the origins of *Il Manganello*.

La reprensione is also a very rare booklet: only one printed, mutilated copy is known, preserved in the municipal library of Piacenza and dating from between 1499 and the first years of the 16th century. However, two copies of the manuscripts exist: a 15th-century paper codex now held in Cape Town (South African Library: Cod. Grey 7.b.5, fol. 24v–34v), to be dated between 1473 and 1483, and the version that found its way into the same Veronese manuscript that contains the *Il Manganello* mentioned above (Verona, Biblioteca Capitolare, MS CCCCLXXI (314), fol. 154r–163v).

The incunabulum consists of five chapters written in tercets in defense of women, whom the extremely vulgar *Manganello* severely insulted, reviled, and denigrated—although Leonardo must have greatly appreciated the latter text, given that we find it (in addition to *L'Acerba* by Cecco d'Ascoli, another work full of misogynistic outbursts) both in his first list of books in the *Codex Atlanticus* (3 □) and among the volumes he took with him to Tuscany after the fall of Ludovico il Moro.

When Pier Soderini, the *gonfaloniere* of the Florentine Republic, commissioned Leonardo to paint the mural of the *Battle of Anghiari* in Tuscany in 1503, he allowed Leonardo to use the rooms of the Sala del Papa in the monastery of Santa Maria Novella to make the cartoon for the work. Leonardo had two boxes of books brought to these rooms (4 □), one of which contained his copy of *Il Manganello*.

Hence the two most important book lists stemming from Leonardo's possessions document his interest in a work of modest literary value but undeniable historical importance, and it is truly surprising that it took so long for us to be able to consult these two complementary texts—*Il Manganello* and *La reprensione*—in a single critical edition published by Diego Zancani in 1982.

For this to happen, however, it was necessary to "deideologize" *Manganello*, ridding it of the stigma of pornography. The work was ignored for a long time because its content was considered indecent and, to put it gently, embarrassingly transgressive; but its marginalization might also primarily be attributed to its possible subversive implications. It was not until Carlo Dionisotti published a seminal essay, "Leonardo uomo di lettere" (Padua 1962) that the way was paved and the groundwork laid to revisit a text that, while uncomfortable, held great potential for understanding Leonardo's world, tastes, and aims. From the first page of his essay, Dionisotti champions the obscene book, granting it a prominent position in a library that was created without any hierarchical canon. In Dionisotti's view, *Il Manganello* fit perfectly within the "casual and spontaneous mix" of Leonardo's library, which consisted mainly of vernacular versions and adaptations—works accessible to readers from a simpler culture—whose richness was nevertheless quite exceptional for a man who belonged to the class of technicians and artists.

Dionisotti, a literary historian, knew *Il Manganello* only via a Paris reprint from 1860 published in 100 copies, which D'Adda had also mentioned in his earlier essay. But Dionisotti notes that he had studied the text of *La reprensione del Cornazano contra Manganello* from photographic reproductions provided to him by a colleague, albeit the mutilated copy preserved in the Municipal Library of Piacenza. Dionisotti concluded his investigation with the hope of soon being able to read an edition of this "important and unknown document" as part of his studies on *Il Manganello*, but 20 years were to pass before this desideratum could be realized. In 1982 Diego Zancani finally produced the critical edition of the two texts that was then published by the University of Exeter, bringing order to a particularly confusing publication history.

First, Zancani was able to prove that *Il Manganello* was written in the middle of the 15th century. Equally important were his reflections on the identity of the author. The explicit on the last folio page in the Codex of Seville reads: *Explicit Manganus D[omi]ni Francisci Mediolanensis*. Zancani attempted to identify this Milanese Francesco via the hypothesis that he might have been Francesco Mangano: although he was unable to achieve any concrete results, he made great progress compared to the sparse previous critical literature. Zancani's results certainly stand out if compared, for instance, to the suggestions of Kenneth

McKenzie in his edition of *Le Noie* by Antonio Pucci (Princeton 1931), where McKenzie mentions several passages from *Il Manganello* without grasping their implicit subtleties.

What is more important, however, is the shift in critical perspective fostered by Zancani's publications. Today, *Il Manganello* is considered a modest but precious piece of evidence of a 15th-century literature that was far removed from the sophistication of Petrarchism, leading it to be marginalized in the following centuries and ultimately relegated to the so-called "hells" of institutional book preservation by zealous librarians who were offended by the text's obscene and openly misogynistic content. Once perceived as a pornographic work of little sophistication, *Il Manganello* is now considered to be a fundamental document of the poetic fronde that helped shape the literary profile of our 15th century—a disruptive element in contrast to "high culture" that thus occupies a position not unlike that later taken by Pietro Aretino's *I Modi*, illustrated by Marcantonio Raimondi, or by writers such as Francesco Berni and Niccolò Franco.

In his *Rime contro l'Aretino* (*Verses against Aretino*), for instance, Franco addresses the spirit of Bembo, asking Bembo to send his greetings not to Petrarch or Boccaccio but to "those from my academy." "It will suffice if, on some street / Berni and Pistoiese and Manganello greet me." Much was at stake, and the author of *La reprensione del Cornazano* cannot have entered the scene merely to denounce the vulgarity of *Il Manganello*. The praise of homosexuality, which was openly defended by this text attributed to Francesco da Milano, and which found fertile ground in the upheavals of 15th-century Italian culture, was perceived as a potential threat to the established order. This was not just a matter of rebuking a custom or placing it on the index, but of framing a discourse that would secure the theological and doctrinal field. What was feared was not the rude pornography of its verses, but the subversive nature of a text that was "published" at a very delicate historical moment, when great upheavals in secular society and in the religious sphere were looming in 16th-century Europe.

Translated from the German by Michael Thomas Taylor

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Da Vinci's Uncompleted *Book of Water*

Marianne Schneider

Leonardo's Lists

In nearly all of Leonardo's manuscripts, we encounter lists again and again. These include lists of books in his library (2 □; 3 □; 4 □), lists of rare words in which he took the poet Luigi Pulci in the *Codex Trivulzianus* as a model (108 □), lists of his belongings, a list of places where he'd hidden his money, lists of expenditures on gifts for his darling Salaì, a list of expenditures for his mother Catarina's burial (these latter two inspired Freud to provide interpretations); but often they are lists to prevent him from forgetting thoughts on a certain topic, or on things that he wanted to write or research in the future.

But the lists that he drafted on the subject of water are different. For example, *Paris MS I* (which stems from around 1495/6, 10 years before the *Codex Leicester*) demonstrates Leonardo's approach to the terminology of water. It appears under the heading "Beginning of the Book of Water."

> A pond is a body of water of some breadth and depth that hardly moves. In its nature, a chasm is like a pond though differing in one respect, namely the water that flows into a pond nowhere froths, while the waters that plunge into a chasm seethe and rush back up because they turn ceaselessly.

He defines a puddle, an abyss, a river, a lake. Later he says:

> A spout and a spring are the beginnings of bodies of water, but the one moves upwards and the other only has a sideward motion and comes from some cave. Submerging is what it is called when things go under the water.

After nearly 20 terms are explained in this way, he suddenly seems carried away by the flow of water, and he notes 64 terms for the motion of water one after another. He begins calmly: "A crossing of waters results when one waterway cuts across the other." But then:

> Ricochet, twisting, turning, rolling, whirling, rebounding, sinking, welling up, flowing down, flowing up, hollows, erosion, foaming, crashing down, falling, pressing, swirling, collisions, corrosion, beating of waves, rippling, seething, crashing down, seep, soak, flood, drain out, sink, winding channel, murmur, rustle, swelling and surging, high and low tide, raging, destruction, chasms, tidal caves, maelstroms, plummet, beat down, bluster, rage, stormy crashings, equalization, evenness, cleaving stone, impacts, seething, flooding of surface waves, gentle flowing, breakage, clefts, openings, lively coursing, turbulence, racing, forceful pressure, confluence, flowing downward, mixtures, turning, falling, leaping upwards, eating away at dams, turbidity.

This is not a systematic list. Rather it represents associations of sound and movement flowing one on the next, where repetitions are not excluded.

10B, 27r of the *Codex Leicester* is titled "23 cases"; it is about water in small amounts: the topic is presented in 23 longer and shorter descriptions. Toward the end, the descriptions become shorter and shorter, followed by a list of "cases" left to be described. Is this another list to prevent forgetting? If you observe the page's motion, you'll notice that a sort of anxious impatience creeps in that something could have been overlooked or forgotten, and so a sort of naming that borders on conjuring takes precedence over detailed explanation.

Leonardo's Interest and the Lack of Tradition

Nevertheless, in comparison to other topics, not only in the lists, but also many other texts concerning water, Leonardo seems deeply engaged, as if water-related things particularly struck a chord with him.

As soon as he began making drawings as a young man, water attracted his attention, a focus that persisted throughout his life. The first drawing of the 21-year-old known to us is of the Arno Valley close to his home (Fig. 1), and in his final months, he was occupied by the construction of a navigable canal between the Loire and the Saône (see the drawing in *Codex Atlanticus*, fol. 920r). From the beginning, he was also interested in the practical aspects of water. He observes water boiling in pots, and the way it moves through pieces of felt, but he can also recommend a military application, for example damming a river in order to flood an entire city, or saving an entire city by inundating a hostile army. He is well-versed in bridge-building and the placement of dams. He learned the elements from the water specialists who taught the young painters in Verroccio's workshop. They transmitted their experiences orally; their knowledge wasn't to be found in books.

Fig. 1. Leonardo da Vinci. August 5, 1473. *Landscape of the Arno Valley*. Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 8 P r (18 □) akg-images / De Agostini Picture Lib. / R. Bardazzi

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Fig. 1. Leonardo da Vinci. August 5, 1473. *Landscape of the Arno Valley.* Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 8 P r (18 □) akg-images / De Agostini Picture Lib. / R. Bardazzi

In *De re aedificatoria* (33 □), Leon Battista Alberti, in some senses a model to Leonardo, writes only once about water that must struggle before it can finally be at peace. Leonardo read this book in Italian translation and it is one of the few written works that contains anything about the topic of water. This has two implications: with regard to water as a material, Leonardo had almost no tradition to fall back on, but also that there was no terminology for it and he had to invent it himself.

The phrase "Beginning of the Treatise on Water" is to be found in *Paris MS A*, fol. 55 v (ca. 1494), followed by a description of the human body and the Earth, as was typical in antiquity, the Middle Ages, and into the early Renaissance.

> The ancients called man a world in miniature, and that is well-said, because indeed man is made of earth, water, air, and fire, and thus his body is like the earth. Just as man has bones as a support and framework for his flesh, so the world has stone to support the earth; as man has the lake of the blood within him, and the lungs while breathing rise and fall, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world; as the veins go out from the lake of the blood, branching throughout the body, similarly does the sea traverse the body of the earth with endless veins of water ... .

Although Leonardo loved this image of the analogy and repeated it in other places, in later years it became clear to him that it wasn't correct, and so he distanced himself from it. But he planned that the "Treatise on Water" would begin with this tradition, as quoted.

Another description of this analogy is to be found in the *Codex Leicester* 3B, 34r:

> Nothing grows in a place where there is no life capable of sensation or growth or thought. Feathers grow on birds and change every year; new hair grows on animals every year, except for a few places such as the beard of lions, cats, and similar; grass grows on meadows and leaves on trees, and every year they are renewed to a large degree. We can thus say that the soul of the earth is the power to grow, and her flesh is the soil, her cartilage is tuff, her blood is underground waterways, the blood lake of the heart is the world sea, its rising and falling is the increase and decrease of blood in the arteries, and for the earth it is the rising and falling tides; and the heat in the soul of the world is fire that is poured into the earth, and the soul, the power to grow, dwells in the fires that emerge at various points on the earth as baths and brimstone quarries and volcanoes like the one on Etna in Sicily and in many other places.

How did Leonardo's methods differ from the tradition of the Middle Ages and early Renaissance? What methods did he use to forge a new and different path in the natural sciences? His library included the works of Michael Scotus (ca. 1180–ca. 1235), Giovanni Sacrobosco (Johannes de Sacrobosco, 1195–1256 (92 □)), Albertus Magnus (ca. 1200–1280), and he surely read them. All of them go to great, nearly frantic pains not to burst the frames of the firmly established structure derived from Aristotle and to find excuses for its obvious contradictions. Leonardo remained indebted to this tradition, particularly in his younger years, but he also had accounts to settle with it. Sometimes he does this in an ironic way, by inventing a conversation partner whom he wants to dissuade from false opinions. But he himself is led by experience, and particularly by his eyes. He is conscious of his approach, and at many points he writes about it in order to guide himself or perhaps a reader. "If you would like to know well all forms of waves and waterways, then look into clear water of limited depth on which the rays of the sun fall, and through this sun you will see all shadows and lights of the aforesaid waves and the things swept along by this water," he writes in *Paris MS F*.

The new thing about his method of research was, as mentioned, his gaze, which noticed individual things that could not be harmonized with the world order that had been considered valid up to that point. These things didn't remain isolated; instead, a new context arose through and around them. The eye of the beholder becomes part of the world. In fact, the notion of "seeing" entered his terminology. Even things "see" each other. The moon "sees" the sun; our seas, shined upon by the sun, "see" the moon, as he describes it, for example, in the *Codex Leicester*.

The *Codex Leicester* (1506–1508, with some content from 1510)

The *Codex Leicester* is a notebook made of 18 sheets folded in the middle, with writing on both sides of each page for a total of 72 pages. Leonardo would completely fill one folded sheet, then lay a second one inside of the first, and so on until the 18th one. He wrote from left to right and correspondingly began writing on the back side of the first sheet. This "notebook" differs from all of his other manuscripts. In it, he took on a topic that he wanted to discuss and that was near to his heart. The individual pages also look different. There are no notes jotted down as thoughts happened to come to him, no sketches on various topics. Every page has a theme or several related themes and is filled with even script, sometimes including drawings that are often at the margins. Here and there a small drawing appears in the midst of the text, as a continuation of a sentence. His prose is also different. He discusses things that he has researched. The main topic is water (Fig. 2).

Fig. 2. Leonardo da Vinci. ca. 1506–1508. *Codex Leicester*. Collection of Bill and Melinda Gates, Seattle, WA, MS Leicester 699, fol. 14A, 14r © Collection of Bill and Melinda Gates, Seattle, Washington

Fig. 2. Leonardo da Vinci. ca. 1506–1508. *Codex Leicester*.
Collection of Bill and Melinda Gates, Seattle, WA, MS Leicester 699, fol. 14A, 14r. ©
Collection of Bill and Melinda Gates, Seattle, Washington
Image:
10_Schneider_Wasser_02

But he doesn't start with water on the first page; instead he starts with the moon (95). His fascination seduces him into conjecturing that there is water on the moon; he explains its unique shimmer with the presence of waves catching the light of the sun. In a conversation with a counterpart who claims that if there were water on the moon, it would fall down onto us, Leonardo replies that then the whole moon would have to fall down too because it is heavier than water, but in reality it is composed like the Earth, with air over the water. On several pages of the notebook, he returns to the topic of the moon, as well as in a conversation with a fictional counterpart who is convinced that the moon produces its own light, while Leonardo demonstrates the opposite. He speaks of the moon a total of six times. The topics remain the same, but each time he adds a new argument or piece of evidence. Thus on page 2A, 2r, there is a drawing and description of the crescent moon, with a lighter circle between its two horns that suggests the whole moon (Fig. 3). Leonardo's line of argumentation is that the moon does not have its own light, as some think, but rather that the waves on its surface reflect sunlight, and so this example also has to do with water.

Fig. 3. Leonardo da Vinci. ca. 1506–1508. *Codex Leicester*. Collection of Bill and Melinda Gates, Seattle, WA, MS Leicester 699, fol. 2A, 2r. © Collection of Bill and Melinda Gates, Seattle, Washington
Image:
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Fig. 3. Leonardo da Vinci. ca. 1506–1508. *Codex Leicester*. Collection of Bill and Melinda Gates, Seattle, WA, MS Leicester 699, fol. 2A, 2r © Collection of Bill and Melinda Gates, Seattle, Washington

One of the pages of the *Codex Leicester* (2B, 2v) contains the resolution:

> But now I wish to leave aside evidence, which then will be provided in an orderly work in the correct location, and I only wish to occupy myself with finding cases and inventions and writing them down one after another as they come, and later I will give them an order by placing together all of them of the same sort; do not wonder at it, my reader, if here such great leaps from one matter to another are made.

He doesn't stop providing evidence until the reverse page (10B, 27r) and then he switches to listing cases and sometimes tenets, though here and there he does add some evidence or at least an explanation. But by announcing his resolution, Leonardo also expressed his continual inner conflict: He wanted to compose a final work, but in the moment "casi" and "invenzioni" forced their way to the fore, as if they just couldn't leave him in peace. As such, although the *Codex Leicester* differs widely from the other manuscripts, we shouldn't regard it as a finished work about water. On B15, 15v, toward the end of the notebook, Leonardo suddenly writes a list at the end of the page, which he entitles "Organization of the Book of Water."

> First book of water in itself. Book 2 of the sea. Book 3 of underground waterways. Book 4 of rivers. Book 5 of the various properties of the sea floor. Book 6 of obstacles. Book 7 of gravel. Book 8 of the surface of the water. Book 9 of the things which move upon it. Book 10 of the protective embankments of rivers. Book 11 of conduits for water. Book 12 of canals. Book 13 of machines which are turned by water. Book 14 of the raising of water. Book 15 of the things which are consumed by water.

Nearly all of these topics have already been touched upon by this point in the codex. It seems as if he could only name his topics once he had engaged with them in detail. They gradually emerged from his research. But even the research is not final, sometimes he has to review errors, or he comes across new variants of the phenomena he has researched. He wants to recognize laws behind the phenomena, but the way that he puts his research to paper isn't unlike a theme with variations.

On some pages, for example on 12B, 12v, we see a list with qualities of moving water, its weight, its effects, its form, and more. It amounts to a summary of phenomena that have already been recognized and discussed. The main topic of the 13th sheet is obstacles in rivers, and it is therefore closely related to the confluence of waterways. On page 13B, 13v, the obstacles themselves are the topic, an approach which reaches its climax on 13B, 24r, where the depiction of each “case” is accompanied by a drawing on the right side. This is also clearly a list. It has assumed an independent identity as a well-rounded and self-contained register of drawn and described forms. Here neither haste nor fear of forgetting prevails. In it, the obstacles have found their language and their image. But that doesn’t mean that the topic has been handled exhaustively, it is taken up several more times in the same codex and in other writings.

14A, 23v shows another list-type enumeration. The topic is water falling through the air and through pipes. The “cases” are listed associatively, thought takes its course unimpeded: in the case of falling water, he thinks of the pliable surface of water, which reminds him of droplets, cohesion, and all of the qualities of droplets, which all have already been explained in the same codex. From there, he’s taken by larger droplets, raindrops, and finally bubbles. When a series of images passes before his eyes, he either cannot stop it or does not want to, even if it concerns a topic that he has already discussed one or many times. He abandons himself to the stream of images without reservation.

But he doesn’t get stuck on the details, everything is embedded in a larger context. Goethe describes the same method in the foreword to his *Theory of Colors.* “Every act of seeing leads to consideration, consideration to reflection, reflection to combination ... .”

One of the major themes in the *Codex Leicester* are *nichi* (an usual name for seashells, which are usually called *conchiglie*) in connection with the biblical Flood (61 □), that is, with large-scale geographical changes (59 □). Leonardo also covers the topic in other manuscripts such as *Codex Atlanticus*, *Paris MS E* and *Paris Ms F*. The question is: where do the seashells that are found on mountains come from? In his youth he had already seen shells in stone—not the shells themselves but their fossilized likenesses—in the mountains near his home. He saw them again when some farmers from Parma and Piacenza brought a sack full of shells and corals from their region to his workshop while he was working on a giant equestrian statue for Francesco Sforza. On the third page of the *Codex Leicester*, where he has a great vision of the Danube valley and shows that Europe was once largely covered in water, the mountain shells cross his mind again.

> The Danube pours into the Black Sea, which once reached Austria and Albania, filling the lowlands that the Danube flows through today; and as a sign of it we have oysters, clams, sea snails, mussels, and the bones of large fish that are still to be found on high-lying slopes or in the aforementioned mountains.

The next page, “Of the earth itself,” further discusses major geological themes. At the end he notes: “You must now prove that the shells, nearly all kinds, are only to be found in salt water; and that in Lombardy there are shells in four different high-lying areas ... .” The reasons provided are radical transformations land and water, and the biblical belief in the Flood, which it would be misguided to debunk. In the pages that follow, he returns to this topic in longer or shorter passages, until finally on page 8B, 8v “Of the Flood and the seashells,” there appears a long discussion with a fictive opponent representing those who believe in the Bible. The topic of shells is continued on pages 9A, 9v and 9B, 9r. 10A, 10r is about rivers constantly changing the face of the Earth by “sawing through” mountains, making the layers of stone visible. Slowly and subtly, Leonardo turns to the topic of shells again, with new details and new arguments. In the *Codex Leicester*, the topic of shells comes to an end with a vision on page 10B, 10v:

> When the bosom of the Mediterranean absorbed the regal rivers of Africa, Asia, and Europe, which flowed into it and wet its mountainous shores, for the mountains surrounded it and served it as a dam, there stood the peaks of the Apennins still flooded by salt water as islands in this sea, and Africa, enclosed in its Atlas Mountains, did not yet show the heavens its mainland of broad plains of some 3,000 miles long, and Memphis lay on the coast of this sea, and over the plains of Italy, where birds flock today, fish sailed by in great schools.

Leonardo's writings on this topic are among the deepest and most compelling pieces of argumentation in his writings. After hundreds of years, they are still geologically valid. He does not write in dry, explanatory prose, but rather in a lively and nearly amusing style that is sometimes ironic, a scientific and literary masterpiece.

Another major theme pervades the codex as described: rivers and the shape of the Earth's surface. But rivers, which are nearly the most-discussed topic in the codex, are also viewed from many other angles: the mouths of rivers, the confluence of smaller and larger rivers, various kinds of waves that form on their surfaces and in their depths; how they behave around obstacles, what happens around bridges, locks, and embankments, how a river can be diverted from its natural course. Another topic is the motion of water: waves on rivers, the seas, and on unmoving water, up-and-down motions, eddies, and whirlpools; underground waterways and the secret of rivers that emerge high in the mountains.

But despite his attempt to write a book, even for the author himself, this notebook didn't add up to a completed work on water. In later years, new findings were added, and the topic was never closed. But he was proud of his work on water. When Cardinal Luigi d'Aragona (1474–1519) traveled through several European countries with his secretary Antonio de Beatis, he visited Leonardo at the Château du Clos Lucé at Amboise. De Beatis writes in his diary: "On the nature of water, various machines, and on other things he has, as he himself reports, written countless volumes, and all in the vernacular."

The Point, Next to Nothing

(12 pages from the *Codex Arundel*: fol. 159 and 160 r-v, 204 and 205 r-v; old pagination. Date: after 1508)

The *Codex Arundel* contains a hodgepodge of various texts and was bound by an unknown hand. Some years ago, Carlo Pedretti and Carlo Vecce took it apart and put it back together chronologically. Several decades ago, Anna Maria Brizio identified two groups of 12 pages each that belonged together based on their script, paper, ink, and content. The topic of both groups is water.

According to Brizio, these pages date to the years after 1508, the last decade of the author's life. His approach to the topic was "decreasingly empirical, increasingly abstract and theoretical." The repetition of a few sentences and above all one sentence is a recurring and successive beat. "The point, it is said, has no parts, and therefore it remains indivisible, and indivisible things have no center, and if a thing has no center, then around it is nothing. The point is therefore nothing." After he writes this sentence about the point at the beginning and then two more times, on the next page he begins the "First Book of Water," and in its pages nearly the same sentence about the point is written again and again. He quickly derives the line from the point, and from the transversal movement of the line the surface, and from several surfaces the solid. And finally he arrives at the question: "What is it then, that divides the air from the water?" He tries out many answers, some of which he must reject. In the end he says: "Nothingness divides these two bodies." The strangest thing about it is that when he mentions the point for the very first time, he says that the point is nothing and arrives at the insight: "… and no science can be based on nothingness."

Nonetheless, he continues to reason in this direction: He expands his inquiry, wandering from the point. He reviews the elements once again. On the next sheet he writes "Of the elements" and how they interact.

Leonardo didn't arrive at any conclusion. It's as if he were frightened of the point, which is next to nothingness. Although he titled three separate sheets "First Book of Water," and he addressed water and the other elements, including fire and boiling water and the smoke of a candle that has been put out, in the end, the point remains. He briefly seems at peace when he writes about the interrelated elements, producing absolutely everything that occurs to him on the subject: the weight of water, the weight of air, lightness and weight as such, depths and shallows in water, the infinite—and the question of whether it is divisible and if so what is the result. Once he resorts to a dialogue with a counterpart. "The counterpart says: The point is or it isn't, it can move or it can't, and if it moves, it describes a line." The answer is deliverance, an image, or better, a vision of water in the form of a ball, if this ball of water were located at the center of the Earth and what would be the result. He finds hope again and titles the next page "First Book of Water," but shortly thereafter, the point reappears, a sort of gadfly. He even manages to cope with nothingness by precluding it; on another page of the *Codex Arundel*, he notes: "That which is called nothing is found only in time and in words. In nature there is no nothing."

"Leonardo doesn't think in concepts ..." said Karl Jaspers (1883–1969) and Alexandre Koyré (1892–1964) even said that "he didn't learn to think abstractly. But he possessed a wonderful gift for intuition." But the point doesn't belong entirely to abstraction, it also references something concrete. Still, it is not visible, nor is it imaginable, at least not for Leonardo. It also didn't lead to visions.

The last sentence on the last page of the group reads: "The point that lies at the center, with the same distance from the opposing borders and the weighting of each thing which has weight or solidity, changes its name and is called the center."

The Paean to Water

(12 pages from the *Codex Arundel*: fol. 233 and 234 r and v, 235 r, 236 v, 210 r, 58 r and v, 57 r and v.) (Date: ca. 1482–1499)

This group, also assembled from the *Codex Arundel* by Brizio, comes from Leonardo's time at the Sforza court in Milan, approximately between 1490 and 1500, his most productive period. More than ten years before writing down the sum of his insights on water in the *Codex Leicester*, Leonardo engaged intensively with the question of underground waterways and the water in them, which flows upward contrary to its nature. The sentence that is his point of departure is repeated a total of six times at various points: "Water, whose life-giving moisture is a gift to this arid earth ... ." Generally, it is followed by a sentence about the reason why water sometimes flows upward, against its natural urge to flow downward; an analogy. "... and the cause, which moves the liquids in all kinds of living bodies ... ." One image galvanizes him in particular: "And just as the water rises from the lower part of the grape vine into a branch that has been cut, and falls again on to the roots, and penetrates these, it is the same thing that water does when ... ." Two further examples are blood in the human body flowing out of a head wound and water that flows up out of the deepest depths of the ocean into the peaks of mountains, breaking through the soil and then following its natural course again on the surface of the Earth, flowing into the sea. The water cycle, human blood circulation, and the circulation of sap in plants is described: water, never at rest. This is repeated on every page, often word-for-word, sometimes with variations, little additions about the formation of clouds, rain, or snow, for example. The sentences are pulled into these images again and again, as if into the eddies of a whirlpool. Sometimes they seem like a repeated musical riff. Analogies always fascinate him. Everything is connected to everything, he notes to himself elsewhere in a sentence citing the Greek philosopher Anaximander (ca. 610–after 547 BCE). In this case, it cannot be that he no longer remembers things that he wrote long ago, as he says elsewhere. Nevertheless, he repeat nearly the same thing on nearly every page. Is he trying to drill it into himself or his readers, so that it can't be forgotten? But there's really nothing to agonize over in these repetitions, they're always images. Water that flows upward really is a strange thing. Little by little, though his prose frees itself from any will to explain anything or to clarify anything a second time through repetition, and gives in to the powerful rhythms of a wide-eyed depiction, nearly an evocation of water, which Anna Maria Brizio calls his "paean to water."

> Water consumes the high mountain peak. Water loosens great boulders and rolls them away. Water drives the sea from its old shores because it causes the ground to rise with alluvial soil. Water shakes the high banks and crashes down; never does it display constancy, were it not to immediately spoil its nature. With its brooks, water seeks the valley's every slope, here it takes and there it leaves new soil. There are many rivers, as we would say, through which the entire element has flowed and which have many times returned the sea to the sea, and every piece of the earth, however high it may be, has already once laid upon the sea floor, and every depth of the sea, however deep it may be, was once the core of a tall mountain. And so it is sometimes harsh and sometimes violent, sometimes acrid and sometimes bitter, sometimes sweet, sometimes thick, sometimes thin, sometimes injurious or fatal, sometimes healthful or poisonous. Thus we would say that it transforms into as many various natures as there are places where it flows. And just as a mirror takes on the color of that which it reflects, so it takes on the nature of the place where it flows. Healthful, injurious, loosening, blocking, sulfurous, salty, sanguine, melancholy, phlegmatic, choleric, red, yellow, green, black, blue, oily, greasy, thin. Now it ignites fire, now it extinguishes it; warm or cold; now it takes, now it gives, now it hollows out, now it piles up; now it topples or reinforces; now it fills or empties; now it flows quickly, now slowly; now it causes death, now life; now creation, now privation; now it nourishes, now it does the opposite; now it tastes salty, now stale, now it overflows the broad valleys with its floods.

This is what some of this "paean" sounds like. Claudio Scarpati, who dedicated a detailed study to Leonardo's prose, points out similarities with liturgical hymns, and in these pages he also hears precise echoes of Dante's *Divine Comedy* (21 □) while Carlo Vecce hears Bible verses.

Leonardo concluded his writings on anatomy as planned. He left his writings on painting to his student and friend Francesco Melzi (Life and Legacy D □), and in the final years of his life, he also started working with him on their compilation. But despite his many plans and attempts, he didn't manage to complete his book about water. It certainly would have occurred to Leonardo that water cannot be represented in drawings to such a great extent as anatomy, and that he would therefore have to rely on language.

Fig. 4. Sketch of a stream that flows around an obstacle, creating waves that resemble braided hair. Leonardo da Vinci. ca. 1510–1513. Royal Library, Windsor. Inv.: RCIN 912659v. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

But two of the artist-thinker's characteristics converge at this point: On the one hand, there is his peculiar habit of digressing from his main topic because he doesn't want to lose sight of the details jostling forward in his mind, and so he often noted down everything that he later wanted to write on the topic. This is evident on some pages of the *Codex Leicester*, for example, where he only makes list of phenomena to be explained or proven. On the other hand, there is his unswerving, unbreakable patience when observing a phenomenon, which becomes particularly apparent with regard to the various appearances of water. The many description of waves come to mind, with their motion on the water's surface, underwater, and when meeting land. Mr. Palomar in Italo Calvino's book of the same name becomes nervous when observing waves and leaves the beach. His clamorous, meddlesome ego prevents him from researching further. Leonardo's ego didn't exist while observing, he himself became a part of nature, became part of the movements, and not just for a short while, but for a lifetime (Fig. 4).

Fig. 4. Sketch of a stream that flows around an obstacle, creating waves that resemble braided hair. Leonardo da Vinci. ca. 1510–1513. Royal Library, Windsor. Inv.: RCIN 912659v. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

Image:
10_Schneider_Wasser_04

Translated from the German by Amanda DeMarco

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“Many children will be mercilessly beaten from the arms of their mothers … and then crushed”: Leonardo and the Media of Horror

Frank Fehrenbach

Secular fantasies of the end of times were a signature of the modern era, long before the alliance of technical and moral progress that people still believe in today in the Far West and the Far East. The catastrophes of antiquity were cyclical natural events that served to renew the world and restore order. The Christian understanding of history, on the contrary, was informed by the end of the world; even in the modern era, it followed on the heels of technological revolutions like a shadow that could not be thrown off. Since the second half of the previous century, we have been frightened by six major apocalyptic scenarios: population explosion, nuclear war, nuclear disaster (“maximum credible accident”), ecosystem collapse (ozone depletion and *Waldsterben*), and the increasingly dominant topic of climate change, while the current pandemic disturbingly recalls the older cyclical models of demise. The dark clouds of the “Robocene” are already gathering on the horizon, ready to make the “Anthropocene” the shortest of all of the geological eras (the fourth and final humiliation after Freud’s three “insults to humanity”?). Panic has always been the dictate of a moment that denounces skepticism as a betrayal of the imperative for action. This phenomenon can also be observed in the discursive mechanisms of the current epidemic event.

Contrary to the ubiquitous belief in technology-induced apocalypse (this belief itself is a typically modern interweaving of guilt and fantasies of omnipotence), the theory that processes immanent to nature must themselves lead to great and possibly ultimate catastrophes can be traced back to the Late Middle Ages and the early modern era. In 1517 the Roman Curia even had to intervene against the panic raging in Central Europe and Italy that a second flood would soon occur, this time caused not by God but by the position of the planets. At that point in time, Leonardo had just left Rome in order to spend the final two years of his life at the court of the French king. The feelings of doom at that time, which – analogous to our times – were largely stoked by the relatively new mass media of book and image printing, must have fascinated him, completely independent of their plausibility. (Leonardo did not believe in astrology.) If prognostication leads to action, its power can be attributed to the singular power of imagination, that is, its power over the emotions of their audience. Without these mental images, a Roman craftsman had no compelling motive to withdraw with his family and provisions to the Alban Hills in anticipation of the coming flood (as it apparently often occurred).

In fact, Leonardo himself enjoyed engaging with panic literature. His dystopian fantasies were often accompanied by explanations that reveal the mechanism of the manipulated imagination. Horror is most effective in the future tense. When “prophesying” for example, that children will be beaten from their mothers’ arms, thrown on the ground, and crushed (“fieno tolti … e lacerati”); the title refers to nuts and olives (*Codex Atlanticus*, fol. 393r). Such products of psychological tension (violence) and paths for diverting it (humor) are an exemplary embodiment of Leonardo’s physical psychology. Leonardo could not ignore the fact that language seems to be a particularly well-suited medium for creating strong mental images. As is well known, not only was he of the opinion that human culture had its origin in the invention of images and graphic symbols (a topic that is also very current today); Leonardo argued with nearly aggressive insistence that images are incomparably more impactful and therefore more effective than writing (see the first part of Leonardo's posthumously compiled "Libro di pittura" (*Book on Painting*) (Life and Legacy D □).

The power of images strikes and moves their viewers. They compel their viewers, Leonardo writes, to repeat the same "lustful actions" (*atti libidinosi*) that are depicted in the image (*Libro di pittura / Codex Urbinas*, fol. 14r). Paintings drive people to impose harsh privations upon themselves and undertake dangerous pilgrimages to visit religious images and throw themselves on the ground before them, "as if the [depicted] divinity were present and alive" (ibid. fol. 3v). Viewers flee from terrifying depictions because the images rattle their nerves via their eyes, causing their muscles to move (ibid fol. 13v–14r). The *erotic*, the *holy*, and the *horrifying* in painting moves the viewer's senses, mental images, and limbs. But the communicative power of strong themes in painting is possible only because they are based on peculiarities of media and the physiology of the senses, which allow images to affect viewers more strongly than other art forms, and even more strongly than perceived reality itself.

We can observe this phenomenon with nearly clinical clarity in the reaction to the so-called "images from Bergamo" in current epidemic policy. An image taken by a young flight attendant's smartphone on the evening of March 18, 2020, is of particular significance. The photo of a convoy of seven to eight military vehicles bringing coffins of Covid-19 victims to the crematoria near Bergamo became a "medial bomb" (Lucien Scherrer, *Neue Zürcher Zeitung,* May 30, 2020). By March 16, the French president was already speaking of a war against the virus; on the evening that the photo spread via mass media, Macron's American counterpart predictably escalated this statement: "our big war." Hardly any politician or journalist in Germany missed the opportunity to justify the lockdown regulations, which were tightened immediately thereafter, by saying that we must do everything possible to avoid the "images from Bergamo." The cropped photo suggested an immeasurable number of military vehicles (in reality it was 13, hardly more than those pictured). More importantly, the snapshot—and this would have fascinated Leonardo—unintentionally recalls an iconic scene from Wolfgang Petersen's epidemic drama *Outbreak* from 1995. In the film, the military moves into the small Californian town of Cedar Creek and threatens to wipe it out. On the day that the photo was taken, *Outbreak* was number five on the list of the most-watched *Netflix* films worldwide. The virologist played by Dustin Hoffman in the film mentions the common location of physical and psychological infection, in a comment that is wonderfully ambivalent: "The common bond is the movie theater!"

Technological reality shaped by physical images and visual desire was at the center of Leonardo's theory of culture—probably for the first time in the history of ideas. "Paintings," (i.e. pictures, diagrams, graphic signs etc.) prefigure the transformation of "first nature" into "second nature" through technology. This is possible because images take possession of their audience's imagination. Today, there can be no doubt that images have become a decisive engine for political decisions, particularly since the rise of the spread of photographs via mass media and particularly since the super media of the internet. The current emptying of public spaces and the immobilization of the population by lockdowns has in effect given political decision-makers new room to maneuver because the pressure of politically relevant images as a whole (not just images of the pandemic) has ebbed. The fact that these images can return with full force in the public media space could be observed after the events in

Vienna on November 2, 2020, even if the executive branch imperiously demanded that the populace refrain from distributing these images.

Leonardo's spectacular group of ten drawings depicting catastrophic hurricanes and flooding was probably created during the time of the prophecies of doom in Rome (Fig. 1). Never before in the history of images had such an overwhelming power of destruction been portrayed. Giant cyclones rampage across landscapes devoid of human life, burying everything in flash floods. Lightning strikes set forests ablaze. Large cities are obliterated by landslides. The viewer finds themselves in the midst of the action. Spatial distances can now hardly be determined; ultimately concrete distinctions dissolve into this seething chaos that for Leonardo reigned at the beginning and end of the world.

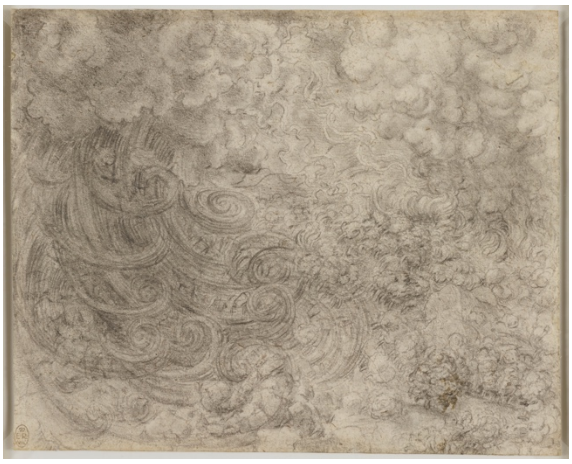

Fig. 1. Leonardo da Vinci, *A Deluge*, ca. 1517–1518. Royal Library, Windsor. Inv.: RCIN 912384. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

Fig. 1. Leonardo da Vinci, *A Deluge*, ca. 1517–1518. Royal Library, Windsor. Inv.: RCIN 912384. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

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11_Fehrenbach_Leo_Medien_01

The "Deluge Drawings" (61 □), which have been held at Windsor Castle for hundreds of years, represent the culmination of the characteristic aspect of Leonardo's landscape depictions since the 1480s: the threatened stability of solid ground, constantly gnawed at by water and wind. Particularly after 1500, Leonardo's landscapes appear to be painted and drawn prognostication, warning of a catastrophe. The viewer finds the suggestive power of these crumbling, tottering, bursting, or storm-whipped formations to be irresistible because they are pulled into the image in a positively psychological way. The flowing transitions of the *sfumato* and the bundled but flailing lines give the viewer not a moment's rest. In an early manuscript, Leonardo had noted that the eye cannot stay still when it observes moving water. The object's dynamic nature imposes itself into the process of perception. Leonardo's life-long obsession with flowing water led to unique graphic interpretations that seek to create an experience of visual immersion in these late drawings of catastrophe.

At the same time that Leonardo made his era's feelings of doom graphically productive, his anatomical investigations concentrated on the movement of blood in the human body's vascular system. Their graphic realization bears striking resemblance to the "Deluge Drawings" (Fig. 2). The swirling motion in the chambers of the heart seems like a hurricane within the body, delicately contained by the blood vessels. For Leonardo, these flowing movements within the body were also based on antagonisms. The vortex of blood, he once wrote, generates heat through friction, which would set the body on fire from within were it not for the cooling of the lungs (Windsor, Royal Library inv. RCIN 919062r). The main purpose of the movement of blood through the arteries—transporting nutrients to the body's periphery—was at the same time counteracted by the precipitation of life-sustaining substances on the walls of the vessels, which ultimately leads to the death of the organism (ibid. inv. RCIN 919027v). The pulse of the living organism ceaselessly digs its proper grave. The late "Deluge Drawings" are a visualization of life processes turned inside-out, constantly working toward their own demise.

Fig. 2. Leonardo da Vinci, *Blood flow through the aortic valve*, ca. 1512–1513. Royal Library, Windsor. Inv.: RCIN 919083v. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

Image:
11_Fehrenbach_Leo_Medien_02

Fig. 2. Leonardo da Vinci, *Blood flow through the aortic valve*, ca. 1512–1513. Royal Library, Windsor. Inv.: RCIN 919083v. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / Bridgeman Images

Only that which strives to survive *and* accomplishes its own downfall is *alive*, according to the paradox described by Leonardo. In Leonardo's radically immanent cosmology, there is no metaphysical actor who saves the world and its bodies from sliding out of balance or into chaos. In the current pandemic, the populations of the wealthy industrialized, Western nations experience this underlying interweaving of life and death as an outrageous shock. But only dead matter maintains a motionless equilibrium. The erosive power of wind and water, writes Leonardo late in his life, will cause mountains to soon be leveled and rising sea levels will cause the continents to be completely covered by water: "and the earth will be uninhabitable" (Institut de France, *Paris MS F*, fol. 84r). This scenario also has a certain undeniable modern-day relevance. Leonardo was familiar with it from the writings of Albert of Saxony (whom he cites) and Jean Buridan (14th century), but Leonardo inverted the argument from the realm of divine providence into geological prognostication. For Leonardo, antagonism and conflict were not merely the expression but also the price of living on Earth. He never doubted that life in its fragile beauty is worth this price.

Translated from the German by Amanda DeMarco

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Fehrenbach, Frank. 1997. *Licht und Wasser. Zur Dynamik naturphilosophischer Leitbilder im Werk Leonardo da Vincis*. Tübingen: Wasmuth.

———. 2019a. "Apocalisse a Roma." In *Leonardo a Roma. Influenze ed eredità.* Exhibition catalogue Villa Farnesina, Rome, 3.10.2019–12.1.2020, edited by Roberto Antonelli, Claudia Cieri Via, Antonio Forcellino, and Maria Forcellino. Storia dell'Accademia dei Lincei. Catalogue 6. Rome: Bardi Edizioni / Accademia Nazionale dei Lincei, 143–154.

———. 2019b. *Leonardo da Vinci. Der Impetus der Bilder*. Berlin: Matthes & Seitz.

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Leonardo’s Vision of a Science of Practice

Jürgen Renn and Matthias Schemmel

Peruse me O reader, if you find delight in my work, since this profession very seldom returns to this world, and since the perseverance to pursue it and to invent such things anew is found in few people. And come men, to see the wonders which may be discovered in nature by such studies.
Leonardo da Vinci
Codex Madrid I, fol. 6r

The major contribution of Renaissance craftsmen, artists, and engineers to the emergence of modern sciences has long been known. But what precisely was their role? Did they enrich academic scholarship with new practical knowledge? Was their practice the precursor of experimental methods? Were they themselves early representatives of a new intellectual type that used the resources of traditional ancient and medieval science to master the technological challenges of their time? All these aspects certainly played a role and are reflected in Leonardo’s works. He is often seen as the precursor of a later generation of scientists, from Galileo (1564–1642) to Newton (1643–1727) who, more than a century after him, made full use of the potential already visible in his notes and laid the basis for modern science.

This perspective, however, presumes that the development of science from its beginnings in antiquity to its further development in Islamic countries, medieval scholastics, and the Renaissance, must have more or less inevitably led to modern science as we know it today. For it is only on this background that we can give Leonardo the status of a “precursor” who anticipated many topics addressed by Galileo and his contemporaries, but failed to bring them to the level of methodological maturity that was supposedly the hallmark of the Scientific Revolution of the early modern period.

The intensive studies of Leonardo’s manuscripts in the past decades suggest a different picture: that of an intellectual, artisanal, and artistic practice that was not yet as clearly divided into different spheres of understanding the world as would increasingly be the case from the Scientific Revolution onward. Looking at Leonardo’s studies of the problems of optics, mechanics, technology, bird flight, anatomy, botany, and natural philosophy, for example, we see that they often cannot be isolated from each other without losing the very meaning these studies had for him and his quest for knowledge.

This is not just because the way he investigated these problems was frequently erratic and associative, with his thoughts scattered over various notepads, which makes it very difficult for us to now reconstruct the labyrinthine paths of his thoughts. In fact, Leonardo often created connections that later on were lost again as knowledge became increasingly specialized and canonized. Whereas some of these connections may only have been ephemeral, in other cases generations passed until people stumbled upon their real meaning again. The connection between fossils and the geological history of the Earth is one such example (59 □; 60 □).

But these sometimes striking feats of anticipation should not be viewed as a simple expression of Leonardo as a genius ahead of his time, rather they reveal the enormous potency of contexts for the history of science—or to put it more precisely, the role of different knowledge network topologies for the importance of individual components and for enabling specific insights. Sometimes these contexts shifted so much that they only facilitated similar insights again in epochs far distant from each other, in a historical sequence that was not necessarily linear and progressive but sometimes cyclical. Only against this background can we understand the surprising similarity between Leonardo's insights and those of scientists like Galileo a century after him, as well as Leonardo's completely different conception of science.

In the field of mechanics and kinematics, Leonardo offered many surprising insights that indeed partly anticipated the realizations of Galileo and his contemporaries, such as his insights into the essential features of the accelerated motion of falling bodies and the methods for investigating it (see Example 1, below), his understanding of the dynamics of the pendulum (see Example 2), and his grasp of the directional character of forces (e.g. in the case of the bent lever) and of the indifferent equilibrium of scales (see Example 3), to name only a few.

Later history tells us that these insights depended not only on applying experimental methods, but also on specific prior knowledge and the awareness of certain theoretical approaches, especially knowledge of the medieval traditions of the graphical representation of changes and of the *scientia de ponderibus*, the latter being originally derived from the Arabic tradition of the theory of weights, and the comparison of the *scientia de ponderibus* with Archimedes' theory of the center of gravity.

Scholars in the 16th century pitted these different approaches against each other, sometimes one-sidedly. It was only Galileo and his contemporaries who first combined them into a consistent system that helped to secure the aforementioned insights. Leonardo was able to anticipate these insights thanks to his astonishingly broad view of this literature, his undogmatic willingness to extract convincing ideas from widely different sources, and his critical gaze in repeatedly checking his findings experimentally.

In other words, it is Leonardo's characteristic knowledge network, including what he had adopted from the books he had read, which emerges as the intellectual background that makes him appear as a precursor to Galileo. This background was further shaped by the comparable cultural and social background which presented Leonardo and his contemporaries, and the generations directly afterwards, with the challenge of mobilizing available knowledge to master the great technological challenges of their time, including war technology, architecture and art, and problems of urban and landscape planning.

In contrast to the writings of Galileo's period, however, a closer look at the contexts of Leonardo's contributions to theoretical mechanics in his notebooks reveals them as rather isolated and often merely marginal flashes of insight, appearing outside of a sustained scholarly discourse, let alone a deductive ordering. In fact, their context was different from that of later preclassical mechanics: there is ample evidence that Leonardo's goal in his quest for knowledge was a very unique one. Paolo Galluzzi has emphasized (CR Essay Galluzzi) that he was not concerned with further developing the tradition of mathematical physics dating back to antiquity—a tradition centered on mathematical laws like the law of falling bodies—but rather in directly understanding the prevailing forces in nature and technology that allowed an explanation of the circumstances observed in reality, and not just as an approximation to an idealized mathematical model.

Also Leonardo's optics were not confined to the mathematical model of central perspective, but took account of physiological factors like stereoscopic vision or how visual impressions are transformed by the effect of light and shadow on objects (110 □) and by atmospheric haze. Similarly, Leonardo's understanding of mechanical forces aimed to discover the entire reality, including such factors as the power transmission and friction in a complex gear (118 □; 126 □), the different sounds that could be connected with mechanical movements, and the turbulence that can be observed in water and air, wherein analogies, such as between swimming and flying, played a major role for him. In contrast with later mechanics, he did not work with an epistemic hierarchy that involved first formulating the basic laws of a point mechanics and then deriving the laws of more complex bodies from these basic laws.

Leonardo's science was a science of practice and workshops in which it was impossible to escape reality because it was simply inconceivable to imagine a division of labor between practitioners of theoretical and practical mechanics or between a scientist and an engineer working on the application of theoretical insights. Leonardo's attempts to reach a unified understanding of natural and technical connections were not just motivated by an interest in random details without any theory behind it. He continually summarized his insights in rules, not just craft rules-of-thumb, but rather attempts to link experiential insights with the theoretical traditions with which he was familiar—while mistrusting them because they abstracted from the connections and contexts he regarded as essential.

Leonardo's science occupies a unique intermediate position between the practical knowledge of the craftsmen and later mathematized natural science. He strived for a science of practice with the real conditions as its object and not with idealized models as a substitute. At the same time, his science of practice went far beyond simple craftsman's experience, exploring the formulation of generalized rules and the search for the hidden connections between things—right up to their cosmological dimensions. Although he no longer ran his own "workshop" in the customary sense, but earned his living mainly as an artist at princely courts, his science emerged from the workshops. The development of his interests always included an element of social ambition and the goal of winning prestige. For example, Leonardo's workrooms in the Belvedere of the Vatican were no longer called "bottega" (workshop), which was still the rule at that time, but were already labelled "studio." In science, as in art, he tried to liberate his work from the lower status of craft activity and to elevate it to the level of a free occupation—yet without betraying its practice-based roots and the concrete experience of the workshops.

The way science developed immediately afterwards, as shown in the works of Galileo and Newton, seems at first glance to contradict Leonardo's idea of a science of practice. Although practical knowledge was still important for the development of mechanics even in their times, the successful breakthroughs in its mathematical formulation was actually made on the basis of abstractions that Leonardo had rejected: considering motion in a vacuum, ignoring friction and resistance, conceiving of masses as mathematical points instead of extended bodies, and neglecting the great diversity of properties of real materials. To begin with, such idealizations, which worked very well in celestial mechanics, actually made theoretical mechanics almost useless for practical purposes. Science needed great persistence until it was finally able to incorporate the complexity of reality so that it could push on with calculations ahead of practice, as modern technology-producing science has done since the Industrial Revolution and still does in a way that has literally changed the world.

From this later perspective, it might look as if Leonardo's comprehensive view of science was premature. Science apparently had first to pass through the needle's eye of abstract mechanics to reach a richer depiction of the world. But in this context, it is interesting to observe that the analytical mechanics developed in the sequel of Newton and Euler (1707–1783) in the 18th and 19th centuries, which employed increasingly abstract mathematical concepts and methods, became at the same time more able to take the "accidental" circumstances of the real world into account. The constraint forces that restrict the possible motions of a physical system, and the dissipative forces that may lead to the reduction of total energy in such a system are fundamental cornerstones for an analytical treatment of physical problems of this kind.

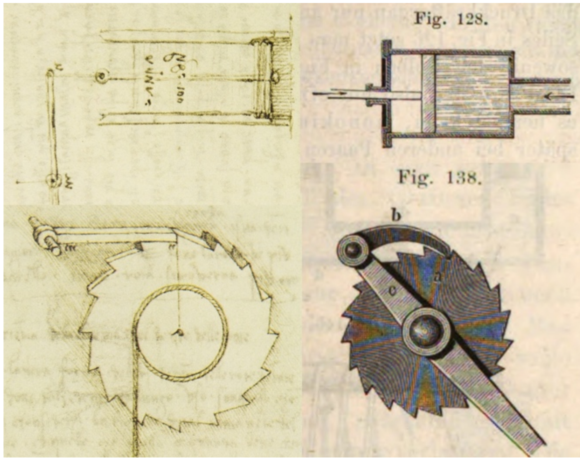

Fig. 1. Above left: piston and cylinder in Leonardo da Vinci. ca. 1493–1499. Codex Madrid I. Biblioteca Nacional de España, Madrid, Ms. 8937, fol. 150r (detail). Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra.
Above right: piston and cylinder in Franz Reuleaux: The Kinematics of Machinery. Outlines of a Theory of Machines. London: Macmillan and Co. 1876, p. 174, fig. 128 (see also Bayerische Staatsbibliothek Munich, Math.a. 206 ld-1, p. 167, urn:nbn:de:bvb:12-bsb11318329-2).
Below left: ratchet in Leonardo da Vinci. ca. 1493–1499. Codex Madrid I. Biblioteca Nacional de España, Madrid, Ms. 8937, fol. 1117r (detail). Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra.
Below right: ratchet in Franz Reuleaux: The Kinematics of Machinery. Outlines of a Theory of Machines. London: Macmillan and Co. 1876, p. 180, fig. 138 (see also Bayerische Staatsbibliothek Munich, Math.a. 206 ld-1, p. 173, urn:nbn:de:bvb:12-bsb11318329-2).
Both authors belong to a tradition dating back to antiquity of looking at machine elements that can be assembled to make complex machines. Reuleaux was familiar with parts of Leonardo's works, but not the Codex Madrid, which was only rediscovered in the 1960s

Since antiquity, technical mechanics—related to the construction and function of machines—has developed in parallel to theoretical mechanics, which eventually became the foundation of modern physics. Much more than a simple application of theoretical mechanics, technical mechanics developed its own independent concepts beginning with the reduction of complex to simple machines in the work of Heron of Alexandria (10 □). Toward the end of the 19th century—again in the context of dramatic technological change, in this case the Industrial Revolution—this development reached a peak with the work of Franz Reuleaux (1829–1905). Reuleaux, a professor at the Technical University in Charlottenburg, Berlin, endeavored to make the engineering science of machine construction an exact science. His book *The Kinematics of Machinery: Outline of a Theory of Machines*, which was published in German 1875 (and in English in 1876), was based on the principle that all mechanisms of solid bodies can be regarded as the relative movement of mechanical pairs of elements that he classified under geometric and topological terms. He created a mechanical alphabet consisting of over 800 models; his ideas were even incorporated into modern computer-assisted machine design. The illustrations of his machine elements are astonishingly similar to Leonardo's machine drawings—they give the impression he sought to connect his work directly with Leonardo's tradition, to which he referred several times in his own work (Fig. 1).

Fig. 1. Above left: piston and cylinder in Leonardo da Vinci. ca. 1493–1499. Codex Madrid I. Biblioteca Nacional de España, Madrid, Ms. 8937, fol. 150r (detail). Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra.

Above right: piston and cylinder in Franz Reuleaux: The Kinematics of Machinery. Outlines of a Theory of Machines. London: Macmillan and Co. 1876, p. 174, fig. 128 (see also Bayerische Staatsbibliothek Munich, Math.a. 206 ld-1, p. 167, urn:nbn:de:bvb:12-bsb11318329-2).

Below left: ratchet in Leonardo da Vinci. ca. 1493–1499. Codex Madrid I. Biblioteca Nacional de España, Madrid, Ms. 8937, fol. 1117r (detail). Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra.

Below right: ratchet in Franz Reuleaux: The Kinematics of Machinery. Outlines of a Theory of Machines. London: Macmillan and Co. 1876, p. 180, fig. 138 (see also Bayerische Staatsbibliothek Munich, Math.a. 206 ld-1, p. 173, urn:nbn:de:bvb:12-bsb11318329-2).

Both authors belong to a tradition dating back to antiquity of looking at machine elements that can be assembled to make complex machines. Reuleaux was familiar with parts of Leonardo's works, but not the Codex Madrid, which was only rediscovered in the 1960s

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While it would arguably be going too far to see Leonardo's goals as a programmatic anticipation of future analytical or technical mechanics, this consideration makes it clear that science does not evolve along a linear route where it is either driven further forward or strays from the path. Rather, we are dealing with a widely branching and in some respects cyclical endeavor that is, in principle, open, and whose breadth leaves space for various asynchronicities.

Leonardo relied on traditional science but at the same time was evidently convinced that one could not simply build on it. From his perspective, one had once again to consider everything anew, to rethink it theoretically as well as check it experimentally. It was always important for him to begin with concrete particulars but with the clear goal of recognizing the structure of a whole. This was a vast enterprise—but one he did not shrink from. His ability to depict, not just in words but also graphically, the connections that he deemed significant helped him in this. At the same time, it rendered his undertaking inimitable, because few people had these special skills.

The science that continued developing after Leonardo's death largely separated the spheres which he had thought of as intrinsically connected, like the link between the technical sphere and that of artistic practice, or the sphere of a theoretical understanding of the world and that of an aesthetic one. This was partly due to institutional and ideological developments, including the continuation—and often narrowing—of established traditions of art and science, which contributed to the long delay before Galileo and his contemporaries could pick up the thread that had been broken with Leonardo. None of this was absolutely inevitable, especially because such separations of the spheres, in view of the challenges of the real world, had always been problematic. This is yet another reason to take a closer look back at Leonardo’s unfinished workshop science.

Example 1: Free Fall

Leonardo’s quest for a consistent understanding of natural and technical relationships repeatedly led him to consider the motion of fall. In contemporary technology this motion played a role, for example, in all machines that worked by percussion. The motion of fall could further be connected with that of cannonballs, objects on slopes, and pendulums. All these objects not only offered inspiration for theoretical occupation but also embodied practical knowledge about natural and technical processes that the theory had to take into consideration. In addition, they provided instruments and procedures that could be used to recreate these processes for purposes beyond practical use and, in particular, to examine them in greater detail—in other words, scientific experiments! Leonardo describes such experiments. For instance, he compares the velocity of fall of two bodies with different weights by using a mirror to determine the position of the lighter one at the moment when he hears the heavier one hit the ground:

> If you wish to establish a general rule concerning 2 falling bodies and to discover which of them descends more swiftly on the condition that they are released at the same time; that they fall from the same height; that they have the same shape, and that one of them is double the other's weight. You shall, therefore, put your ear close to the spot where the descending bodies will hit. And have a plane mirror placed at a great distance, a distance as far as 3 times the fall of the bodies, in a position where the mirror shall reflect the falling· bodies in the middle of their descent. As you release the bodies, have your ear in close proximity to the site of the percussion and your eye upon the mirror in the middle of the proposed path of descent. If you hear the percussion of the major weight at the same time that you see the minor weight in the

mirror which you placed in the middle of the course, you can say that the major body has double the velocity of the minor. (*Codex Madrid I,* fol. 60 f.)

In conceptual and mathematical terms, the motion of fall is anything but trivial. It is by no means obvious what magnitudes play a major role and how they change in the course of the motion. It was here that Leonardo made use of his extensive knowledge from books. In his manuscripts on motion, he mentions Albert of Saxony (ca. 1316–1390), Richard Swineshead (active 1340–1354) and other medieval authors who developed and used a conceptual-mathematical scheme for describing the variation of different qualities, and applied it particularly to accelerated motion. Leonardo equally availed himself of this scheme to describe the motion of fall, as the terminology he used and the diagrams he drew clearly show. Thus, referring to a triangular ("pyramidal") diagram, he described the magnitudes of time, motion, and velocity in the motion of fall as beginning in "nothing" and growing in "degrees of arithmetical proportion" (Fig. 2).

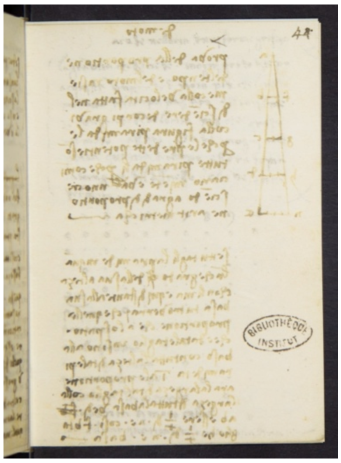

Fig. 2. Leonardo da Vinci. ca. 1495–1500. *Motion of fall*. *Paris MS M*. Institut de France, Paris, fol. 44r. Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS M. Florence: Giunti

Fig. 2. Leonardo da Vinci. ca. 1495–1500. *Motion of fall*. *Paris MS M*. Institut de France, Paris, fol. 44r. Reprint: Marinoni. 1986. I Manoscritti dell'Institut de France: MS M. Florence: Giunti

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12_Renn_Schemmel_Praxis_02

A frequently asked question in the literature on Leonardo and his medieval sources is whether he was the first person to have applied the diagrams of motion to free fall and whether in this way he gained insight into the law of fall of classical mechanics; this states that in a vacuum the speed of descent increases in proportion to the elapsed time and the distance travelled increases proportionally to the square of the time. Indeed, the same terminology and the same type of diagrams are still to be found over a century later in the works, letters, and notes of Galileo Galilei (1564–1642), René Descartes (1596–1650), and Thomas Harriot (1560–1621)—works, letters and notes that ultimately led to understanding the law of fall. After all, from Leonardo's aforementioned statement, we can conclude that he had at least correctly understood that speed increases in proportion to time.

But formulating the question like this neglects the context in which motion was thought about in different ages and leads to later insights being misleadingly introduced into reconstructions of earlier considerations. For instance, in isolated cases medieval authors mention the motion of fall in the context of sophistic arguments about the variation of qualities as an example of non-uniform motion—alongside other examples such as Socrates continually increasing his walking pace! From a modern perspective, it must further seem surprising that Leonardo differentiates between the generation of "degrees of motion" and that of "degrees of velocity" proportional to it. Here he is following medieval terminology but using it in a changed context.

Although Leonardo did formulate the proportional relation between the velocity of fall and time, as is correct from today's perspective, his notes also show that he believed it was equivalent to a proportional relation between this velocity and the distance traversed. The realization that these two proportional relations actually contradict each other was the result of protracted mathematical explorations, which still presented difficulties to Galileo, Descartes, and Harriot. But for them, the motion of fall had already become the key challenge of a more deeply specialized mathematical physics. As we have seen, for Leonardo, the motion of fall in its natural and technical contexts was still part of a broader knowledge network in which he connected medieval concepts and diagrams with considerations, observations, and experiments that brought together widely differing mechanical as well as acoustic and optical phenomena.

Example 2: The Trajectory

The progressive development of war technology, particularly for artillery, altered the challenges faced by the traditional theory of motion. Whereas medieval theorists mainly concentrated on how to explain that a projectile carried on moving after it had left the agent that moved it—be it a throwing hand, catapult, crossbow, or bowstring—the practical context in which cannons were used on the battlefield raised questions about the effect of a projectile, its firing range, and its penetrating power. These, in turn, were a specific function of the quantity and quality of the gunpowder, the size and shape of the cannonball, and the firing angle of the shot. Leonardo's manuscripts document his intensive study of these questions in various places, such as when he asked about the relation of the force of the gunpowder to the weight used to span a crossbow, or when he advised trying out various forms and weights of projectiles for artillery weapons.

In his efforts to represent essential features of a trajectory in drawings, Leonardo combined practical knowledge with theoretical ideas. In one diagram, he constructed a whole spectrum of trajectories that displayed certain overall characteristics, accompanied by a short text with a dynamic explanation of the asymmetrical nature of the paths he had drawn (Fig. 3).

Fig. 3. Leonardo da Vinci. ca. 1493–1499. *Trajectories and pendulum motion*. *Codex Madrid I*. Biblioteca Nacional de España, Madrid, MS 8937, fol. 147r. Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra

Image:
12_Renn_Schemmel_Praxis_03

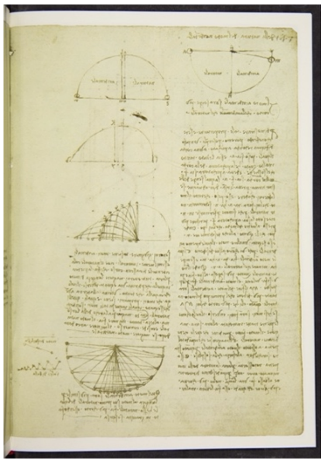

Fig. 3. Leonardo da Vinci. ca. 1493–1499. *Trajectories and pendulum motion*. *Codex Madrid I*. Biblioteca Nacional de España, Madrid, MS 8937, fol. 147r. Reprint: Reti. 1974. I Codici di Madrid I. Florence: Giunti-Barbèra

He clearly tried to capture the existing practical knowledge on projectile motion in a theoretical framework using Aristotle's distinction between natural and violent (or "accidental") motions, and hoped this would allow him to deduce essential features of the projectile trajectory. Contemporary artillery practitioners knew that the path of a projectile is not symmetrical. Its ascending part is longer than its descending part. In the framework of Aristotelian physics, this meant that the violent part of the motion was longer than the natural part. Leonardo noted that this behavior was precisely the reverse of what is given in a swinging pendulum, where the natural part of the motion at the beginning is longer than the following, violent part.

Starting from the dynamic assumption that the highest point of the trajectory marked the exact moment of transition between violent and natural motion, Leonardo drew diagrams of shots with equal force but different launching angles by using lines whose highest point lay on an arc with its center point exactly at the origin of the firing lines.

Yet, for one of the nine trajectories he broke this rule—why? Although Leonardo's construction rules did not specify the exact form of the trajectory, he followed the specification that the declining branch of the path was shorter and more sharply curved than that of the ascending branch, so that he obtained asymmetrical curves corresponding to observation. With increasing elevation, the shots approach symmetry, and with the vertical shot perfect symmetry is reached.

But this construction, when applied consistently, violated another elementary aspect of the practitioners' experience. This was the knowledge that the maximum range would be achieved not by horizontal shots but by a launching angle intermediate between the horizontal and the vertical. This meant that in the construction, the range of a shot should not always simply increase with a declining launching angle. Probably it was Leonardo's insight into this difficulty that led him, in his diagram, to break the rule that the peak of the trajectory must lie on the circle around the origin in the case of the flattest shot.

In the later works of Galileo and some of his contemporaries, we also find the link between the projectile trajectory and other mechanical phenomena like Leonardo's pendulum, for example, a hanging chain or motion on an inclined plane. For Galileo and others, such as his contemporary Thomas Harriot, this developed into a program of graphical construction of trajectories that completely determined their geometrical shape. This program led them to derive the parabolic form of the trajectory, resulting in a more precise geometrical description of the trajectory. But this greater precision meant, at least temporarily, that other accidental circumstances of the motion could not be considered, such as the wind or the shape of the projectile—conditions that were very important for Leonardo's considerations of these phenomena. Thus, the treatment of projectile motion became one of the cornerstones in the development of classical mechanics. At the same time, the idealized way in which this was achieved meant that, for the time being, the results of the mathematical description were useless to contemporary artillerists.

Example 3: The Equilibrium of the Scale

For centuries the question of whether an equal-arm balance deflected from the horizontal will return to its original position when released was the subject of controversial debates in the history of mechanics. An associated problem was that of the bent lever, a type of balance with one kinked arm. How does the force of a weight operate in such a skewed position? And when is the bent lever in equilibrium? In the analytical mechanics of the 18th century, this type of question came under the general heading of constraint motion, but had already been discussed in the Middle Ages by authors of the *scientia de ponderibus* such as Jordanus Nemorarius (early 13th century) in relation to the effect of a weight being dependent on its position in a mechanical device. Jordanus, whose work Leonardo had read critically, introduced the term "*gravitas secundum situm*" (position-dependent gravity) in this context, and thought he could prove on its basis that a balance in equilibrium must always return to its horizontal position.

Leonardo da Vinci was apparently one of the first people to answer this question by referring instead to the Archimedean concept of the center of gravity. He concluded that the deflected scale was a case of indifferent equilibrium. In other words, it does not return to the horizontal position of its own accord, at least if one ignores the materiality of the balance's beam. He explained the general experience that such a balance nonetheless appears to return to the horizontal with the difficulty in constructing a balance whose fulcrum coincides exactly with the center of gravity (Fig. 4):

Fig. 4. Leonardo da Vinci. ca. 1494–1497. *Equilibrium of a balance*. *Codex Forster II*. Victoria and Albert Museum, London, fol. 128r. Reprint: Marinoni. 1992. I Codici Forster del Victoria and Albert Museum di Londra. Florence: Giunti

Image:
12_Renn_Schemmel_Praxis_04

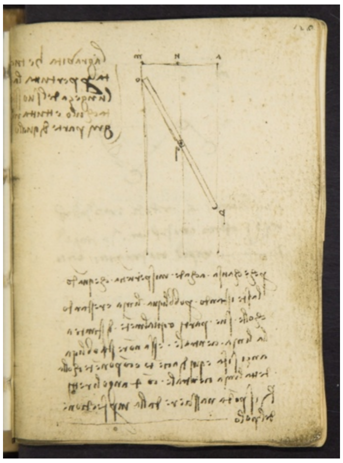

Fig. 4. Leonardo da Vinci. ca. 1494–1497. *Equilibrium of a balance*. *Codex Forster II*. Victoria and Albert Museum, London, fol. 128r. Reprint: Marinoni. 1992. I Codici Forster del Victoria and Albert Museum di Londra. Florence: Giunti

> The heaviness is whole for the whole length of its carrier and whole in each part of it. Why does it happen in experience that, when the beam is along an oblique line and with its parts equally distant from the central line, it does not remain oblique, but rather makes itself horizontal and forming with the said central line 4 right angles? Answer that this comes from the imperfection of the fulcrum. (*Codex Foster*, fol. 128r, translation from Renn and Damerow 2012, 57–58)

For Leonardo, however, the material aspects of the balance, including the dimensions and weight of its beam and the friction of its fulcrum, were just as fundamental to his newly conceived science of practice as the indifferent equilibrium of an idealized scale.

Leonardo also correctly asserted that a bent lever is in equilibrium when the weights on either side of the beam are equal, and their centers of gravity are equidistant from the perpendicular through their common center of gravity (Fig. 5).

Fig. 5. Leonardo da Vinci. ca. 1494–1497. *The equilibrium of a bent lever*. *Codex Forster II*. Victoria and Albert Museum, London, fol. 126v. Reprint: Marinoni. 1992. I Codici Forster del Victoria and Albert Museum di Londra. Florence: Giunti

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12_Renn_Schemmel_Praxis_05

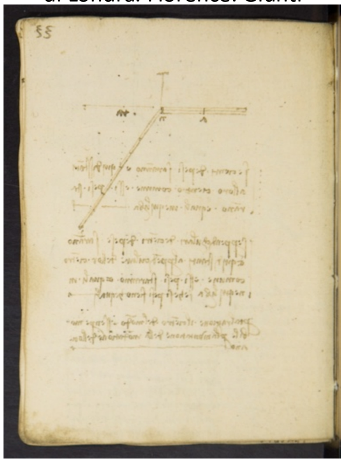

Fig. 5. Leonardo da Vinci. ca. 1494–1497. *The equilibrium of a bent lever*. *Codex Forster II*. Victoria and Albert Museum, London, fol. 126v. Reprint: Marinoni. 1992. I Codici Forster del Victoria and Albert Museum di Londra. Florence: Giunti

Leonardo further drew cosmological conclusions from these mechanical observations and argued that the center point of the Earth was mobile as a result of changing tides:

> When the centers of the weights are equally distant from their common center, these weights will be equal in equilibrium. When the perpendiculars of the centers of the weights are equidistant from the perpendicular of their common center, these weights will be equal in equilibrium, if these weights are equal. For this reason, the center of the world is always mobile because of the change of the tides of the ocean. (*Codex Foster*, fol. 126v, translation from Renn and Damerow 2012, 56–57)

The practice to which Leonardo gave a key role in his science evidently had always also a concurrent cosmological dimension.

Translated from the German by Karen Margolis

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Against Those “Authors Who by Relying Only on Their Imagination Make Themselves Interpreters between Nature and Man”

Paolo Galluzzi

From the 1490s onwards Leonardo made a strenuous effort to assimilate the fundamental principles and rigorous theories of ancient and medieval mechanics, particularly during the almost 20-year period of his first stay in Milan. In the texts associated with this illustrious tradition—from Archimedes to Jordanus Nemorarius, Biagio Pelacani, and also Leon Battista Alberti, to cite just some of the authors studied and read in detail by Leonardo—questions concerning equilibrium, leverage, the balance, and centers of gravity, were handled in a very abstract fashion using strictly geometric methods. Problems relating to the balance, for example, were tackled by considering this instrument as a geometric entity (the beam as a segment, the fulcrum as a mathematical point, and the hanging system—the “*sostentacolo*,” as Leonardo called it—as not influential on the behavior of the system, while the friction between the interacting parts was deemed to be nil). It was thanks to the programmatic elimination of the irregularities and perturbations deriving from the material composition of the mechanical instruments, that ancient and medieval statics was able to achieve—long before Leonardo arrived on the scene—a degree of formalization that was unrivalled by any other discipline (with the exception of astronomy and optics).

During the long, hard process of assimilating the fundamental principles, methods and theories of classic and medieval mechanics, which he studied with a dogged determination, Leonardo demonstrated an increasingly explicit dissatisfaction with the methods used by those renowned authors before him. At the same time, he gradually developed an ambitious scheme to reform the principles of the *scientia de ponderibus* (science of weights), with the objective of extending its field of application to increasingly varied disciplines. These observations and efforts to correct its formulation and expand its horizons progressively gave rise and substance to that which can be described as an attempt to subject ancient and medieval statics to radical reform, based on questioning the fundamental assumptions that had been shared until then by all the key figures that this tradition entailed: the “dematerialization“ of the objects concerned, and the standardization of the space in which the operations are performed.

Leonardo did not aim to dismantle the geometric foundation of the *scientia de ponderibus*. He too hoped to develop a strictly geometric method, albeit not a method relating only to abstract entities such as flat geometric and solid shapes. His was to be a method linked to the bodies of the real world and the tangible factors that mark the perennial battle in the theatre of nature—man included—between force and resistance. A battle which governs equilibrium or its breakage, generates perturbations, presides over operations of lifting and dragging weights, and produces devastating knock-on effects.

Leonardo’s approach was that of a craftsman who was not content to contemplate the *scientia de ponderibus* as an elegant production of abstract speculation, but who proposed to use its theories on a practical level: the architect concerned with guaranteeing long-term stability for buildings; the engineer who aims to construct machinery able to operate for long periods without the need for maintenance; the natural philosopher who strives to understand how the machine of the world works; lastly, the artist, who aims to provide a faithful reproduction of the physical constitution and workings of man and animals. In order to pursue these ends, Leonardo worked on a reformation project of unprecedented complexity, which he hoped could lead to a science characterized by the same formal rigor as traditional mechanics, but able to provide practicable solutions for the manipulation of the mechanical systems of the real world with which engineers and natural philosophers interact on a daily basis.

The manuscripts on which Leonardo wrote his notes and produced drawings from the last decade of the 15th century onward (primarily *Paris Mss. A, C, K, I* and *M* of the Institut de France, the *Codex Madrid I* (8937), the *Codex Forster II*, and, naturally, the contemporary sheets of the *Codex Atlanticus*), reveal his growing dissatisfaction with traditional solutions, together with the first signs of his ambitious reformation project taking shape. This project will continue to occupy Leonardo's mind until the end of his life.

As regards geometric statics, one of the fundamental reasons for his dissatisfaction with traditional solutions was based on the inadmissibility of the decision to remove the material structure of the beam of the scale from the scenario, assimilating the centre of the "real" or "in use" balance (as Leonardo defines the physical instrument) with the mathematical centre of the system (considered an indivisible point), in addition to overlooking the friction between the beam and the instrument support system.

To demonstrate his consistent move away from the traditional science of weights (whose first manifestations date to the period 1490 to 1492), it is worth citing the resolutely explicit *memorandum* on fol. 257r of the *Codex Atlanticus*, dating to 1513:

> Where the science of weights is led into error by its practice.
>
> The science of weights is led into error by its practice, which in many instances is not in agreement with this science, nor is it possible to bring it into agreement. This arises from the axes of the balances upon which the science of such weights depends. These axes, according to the ancient philosophers, were treated as having the nature of mathematical lines, and in some places as mathematical points. These points and lines are incorporeal, whereas practice treats them as corporeal, because this is what necessity demands for supporting the weight of these balances together with the weights on them that are to be judged.
>
> I have found these ancients to be led into error in this judgement of weights, and this error is born because in much of their science they used corporeal axes and sometimes mathematical axes, that is to say mental or incorporeal ... .

Leonardo provides tangible examples of the method to be followed to re-establish a direct and intrinsic link between the abstract theories of the science of weights and "its practice," that is to say with operations carried out in the real world using physical instruments. Traditional mechanics (the "ancient philosophers") established that in order to tip a balance with equal arms and weights suspended in its centre, a small weight simply needed to be added to one of its two ends. Leonardo reformulated this rule so as to consider the effects of the friction produced on the axis of the balance. If this factor of perturbation—ignored by the authors of the *scientia de ponderibus*—is taken into consideration, it becomes apparent that it is not possible to tip the balance by simply applying a small weight to one of its two arms: instead it is necessary to add a weight equivalent to the inertia generated by the friction on its fulcrum. Leonardo consequently disproved the definition of equilibrium (and tipping the balance) formulated by geometric statics: the balance remains in equilibrium even in the event of a small weight being applied to the end of one of its two arms, if this small weight is unable to overcome the resistance generated by the friction between it and the support. Based on this analysis—which presupposes the use of a physical balance rather than its abstract geometric schematization—Leonardo corrects the definition of equilibrium proposed by the authors *de ponderibus*: “Where one weight affects natural gravity only slightly more than the other, it does not cause the balance to move … ” (*Codex Atlanticus*, fol. 257r).

In a sheet of the *Codex Atlanticus*, dating to around 1500 (fol. 393r), a similar line of reasoning led Leonardo to reformulate, in the same rigorous style as the authors of *de ponderibus*, the proposition that governed the conditions needed to tip a “real” balance with equal arms and weights:

> Using a common balance, the heavier weight, that is to say the weight that causes the movement, will be greater than the other by a quantity equal to the resistance operated by the beam; and for the other weight that it exceeds, even the smallest and most minimal amount of gravity is sufficient.

Elsewhere, reiterating that it is impossible to isolate the principles that regulate the equilibrium of the weights on the balance without considering the friction on its fulcrum, Leonardo vigorously denounces the incorrect method of the authors (among whom, in another text, he explicitly refers to Leon Battista Alberti) who overlooked these factors, see *Codex Arundel*, fol. 66r [P 49r]:

> Experience is never at fault; it is only your judgement that is in error in promising itself such results from experience as are not caused by our experiments. For having given a beginning, what follows from it must necessarily be a natural development of such a beginning, unless it has been subject to a contrary influence, while, if it is affected by any contrary influence, the result which ought to follow from the aforesaid beginning will be found to partake of this contrary influence in a greater or lesser degree in proportion as the said influence is more or less powerful than the aforesaid beginning. (Codex Atlanticus, fol. 417r)

Experience attests to a world in which the force is in a perennial battle with resistances and influences. A science worthy of the name has to explain this world to us. In another text, he writes: “If you were to say to me: what do these laws of yours generate, what are they for? I would answer that they prevent engineers and researchers from promising themselves ... impossible things” (*Codex Atlanticus*, fol. 922 (ca.1493–95).

Laws—we should note—not practical precepts; laws used to unmask boastful engineers, but also to direct the efforts of investigators along the clear paths of reality and away from the misty regions of the imagination.

For Leonardo, the authors of the *scientia de ponderibus* tradition fixed their gaze on a level of reality that does not correspond to the real world. Their theories do not consider the friction generated on the fulcrum of the balance, nor numerous other factors that intervene in the operation of the physical instruments: the weight of the arms, the air resistance, the effects of temperature and humidity. Because of this—he admonishes—their elegant treatises cannot be used in practical operations:

> You investigators therefore should not trust yourselves to the authors who by employing only their imaginations have wished to make themselves interpreters between nature and man, but only to those who have exercised their intellects not with the signs of nature but with the results of their experiments. (*Paris MS I*, fol. 102r)

The decisive reference to authors who have used their imagination to construct a level of reality that is distant from the real world, implanting on it a science founded on rigorous proofs, is what fuels Leonardo's attempt to develop a new science of mechanics.

From the last decade of the 15th century, Leonardo outlined a project for the overall reformulation of the *scientia de ponderibus*, so as to propose a new science of statics that was not only more firmly grounded in theory, but which could also be used in practical operations. One should emphasize the interaction between theoretical requirements and practical expectations, an interaction that must not be understood, as is all too often the case, in a hierarchical sense (the experience that guides theoretical generalizations), but as part of a complex dialectical relationship. In fact, theoretical elaboration is proposed by Leonardo as an essential tool for reformulating and qualifying conclusions established on an exclusively empirical basis. While he targets decisive criticism at the abstract analyses of the authors of *scientia de ponderibus* tradition, he displays even more severity regarding those who adopt an exclusively empirical approach to mechanical matters.

The authors of the science of weights developed theories that were refuted by practice, because they were built upon incorrect foundations: "These beams, according to the ancient philosophers, were treated as having the nature of mathematical lines, and in some places as mathematical points. These points and lines are incorporeal, whereas practice treats them as corporeal, because this is what necessity demands" (*Codex Atlanticus*, fol. 257r).

The message is clear: reality cannot be replaced by fiction, nor can material influences be ignored without violating the laws of nature, founded on necessity. These clear statements seem to demolish the entire *scientia de ponderibus* so laboriously learned, as well as the foundations of the mechanics of Archimedes, whose texts Leonardo had eagerly studied (70 □; 73 □).

The examples could multiply. Although not restricted to statics, this reformation project achieved its most advanced results in this field. The fragments of Leonardo's studies that have reached us offer a vision of mechanics oriented toward applications, although not based solely on practice and experience. They also indicate a constant polemic against the authors who supplant the reality perceived by the senses with ideal models, adopting them as primary objects of science. For Leonardo, everything is imperfect and subject to the cosmic law of "consummation," as he would underline in an extraordinary passage, loaded with venomous invectives against the authors who exercise their ingenuity on mathematicised natures. The paradoxes of infinite divisibility are turned against these authors:

> This proves that it is impossible to give or make anything without absolute exactness; for if you want to make a perfect circle by moving one of the points of the compasses, and you admit what is set forth above, that this point tends to be worn away in the course of long movement, then the whole point will necessarily be worn away in a certain space of time and the part will be consumed in part of this time; and the beginning of such consumption will be indivisible in indivisible time … (*Codex Forster II²*, fol. 133r)

Substantially convergent processes of non-passive assimilation of handed-down science characterized other sectors of Leonardo's research: hydraulics, the science of flight, acoustics, optics, and so forth.

The development of Leonardo's studies of perspective reveal the same steps we observe in his approach to the science of weights. The initial phase demonstrates his belief in the perfect correspondence between artificial perspective and natural perspective. Later an awareness emerges that the perspective of painters, based on the visual pyramid, is an abstraction generated by the imagination, which needs to be corrected with the perspective of colors and of "distances," as well as by tackling the complications introduced by natural, binocular vision. The perspective of colors and that of "distances" represent the equivalent in optics of the intrusion of friction and influences in mechanics: they aim to make the objects of science correspond to the natural effects, denouncing the deformations produced by mathematical abstractions.

While his youthful texts counter the unreliability of visual sensations with the certainty of perspective reconstructions, in his later research he rejected this paradigm and evolved his thinking toward a natural science of vision, freed from the artificial simplifications of the perspective of painters.

This view is based on a criticism comparable to that made of the authors of the science of weights. Perspective painters err not in the use of geometry and proportions, but in claiming to replace real phenomena with schemes conceived by the imagination. Leonardo's reform develops in the sense of a strictly quantitative handling of the mechanisms of natural vision, to which he assigns absolute primacy. This research culminates in *Paris MS D*, dating to 1508 (82 □; 94 □), where Leonardo shows how he distances himself from the perspective painters. He is now able to calculate the effects of refraction, a phenomenon unknown to the perspective painters. He also uses a series of extraordinary experiments to demonstrate that the visual power extends across the entire surface of the pupil and is not "reduced to a point as the perspective painters would have it" (fol. 4v). Lastly, he examines natural binocular vision by highlighting divergences compared to reconstructions based on the visual pyramid.

It is not only in his critical review of the laws of linear perspective that Leonardo challenges in a creative way the conclusions established by the authors of geometric optics. He addressed his criticism also toward their interpretations of the rules governing the reflection of solar rays in mirrors of different curvatures.

The motivation that induced Leonardo to take on the traditional interpretation of burning mirrors is the same that we have observed in his approach to the theories of the science of weights: he intended to check whether those laws could be used to actually construct reflective surfaces that meet the operating requirements of craftsmen.

Leonardo's interest in the theory and practice of burning mirrors spanned his entire career. His interest in this subject first emerged during his apprenticeship, in the early 1470s, in the workshop of Verrocchio, who used burning mirrors to smelt metals. (In a memorandum written in around 1515 in *Paris MS G*, Leonardo recalls Verrocchio's use of burning mirrors to weld the sections of the gilded copper sphere destined to be placed on top of Brunelleschi's dome in Santa Maria del Fiore: fol. 84v.) Leonardo's research into the "*ignie*" (as he referred to burning mirrors) was resumed with intensity in Florence between 1503 and 1505. He returned to burning mirrors once again between 1507 and 1508. Lastly, he devoted himself to designing devices to manufacture them during his stay in Rome, between 1513 and 1515.

In his diagrams and notes on a bifolium of the *Codex Arundel* (fols. 84v-88r [P 64r-v]) Leonardo analyses the relationship between the curvature of the mirror and the reflection of the sun's rays, emphasizing that the effectiveness of burning mirrors depends on their capacity to focus the rays in a limited area. He also observes that, in order for the rays to be reflected at significant distances, the mirror has to present a minimum curvature, which can be obtained by taking small arcs from circles of a considerable diameter. Leonardo provides as an example a mirror with a section of the length of one *braccio*, from a circle with a diameter of 400 *braccia* (over 220 meters!): a mirror that is therefore almost flat. He then formulates the general rule: the maximum distance at which the rays are reflected in spherical mirrors is equivalent to 1/4 of the diameter of the sphere. "The mirror of common concavity turns the last distance of the reflected rays to the fourth part of the diameter of the spherical body from whence this mirror is derived" (*Codex Arundel*, fol. 84v).

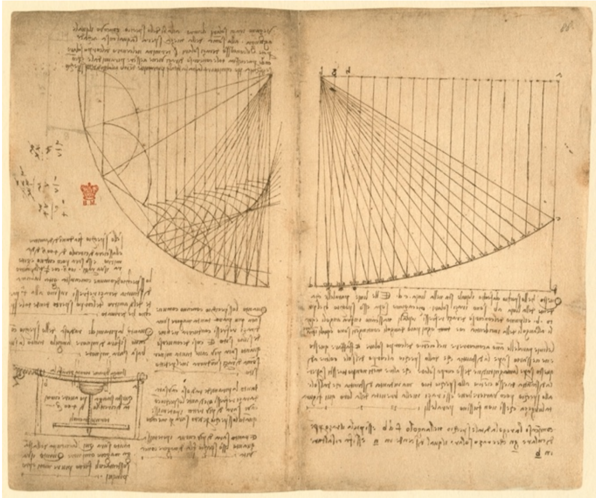
The reasoning is visually illustrated by the diagram on fol. 84v. It outlines the section of a mirror, corresponding to one quarter of a circle, in which the dense network of the reflections of the sun's rays are visualized. The diagram highlights the constant equality of the angles of incidence and reflection of the individual rays. It also shows that the rays reflected on the upper part of the quadrant are dispersed. Vice versa, the rays that affect the lower part concentrate in a small area of almost triangular shape, whose farthest point is identified exactly at the middle of the radius of the sphere. Leonardo thus intuitively illustrates the reason why the burning efficacy is greater in spherical mirrors of moderate curvature: in fact, the rays are reflected in a restricted area, in which there is consequently a strong production of heat.

The drawing in the bottom left margin indicates that Leonardo considered the geometric demonstration as instrumental for the material manufacturing of mirrors. There we can observe a very slightly curved copper shaft, resting on two vertical supports and driven forwards and backwards by a rack and pinion mechanism. By rotating against the template, the mirror acquires the same curvature. Leonardo specifies that the case depicted corresponds to the example mentioned previously: in fact, the "shaft" is an arc of one *braccio* long, belonging to a circle with a diameter of 400 *braccia*. It is obvious that Leonardo is dealing with a question of technology transfer. Using the information assimilated from texts on geometric optics, he proceeds with the construction of a device to test the conclusions reached in his experiments on burning mirrors.

Should the test results be positive, he can start production of mirrors with a high burning efficacy: an exciting prospect due to the notable economic rewards it promises. It is precisely this hope that leads Leonardo to record his reflections in an incomplete manner: in fact, he only partly outlines the mechanisms of the "template"; he also makes use of anagrams and cryptic messages. Leonardo even concealed the identity of the metals he intended to use for the templates and for the mirrors, transforming their names into anagrams, or only citing their alchemical names. It is worth mentioning that this kind of masked approach was highly unusual in Leonardo's manuscripts, which usually demonstrate a high level of transparency.

The demonstration on fol. 84v of the *Codex Arundel* communicates directly with the graphic and textual analysis on the opposite sheet (*Codex Arundel*, fol. 88r [P 64v]) (Fig. 1). In the large central diagram we can see a rectangle, divided into 18 equal rectangles by 17 lines parallel to the shorter sides. Inside the rectangle, Leonardo has drawn a line that seems, at first sight, to be an arc of a circle, or a parabolic section. Leonardo specifies that in this burning mirror all the solar rays converge in the same point, where an enormous concentration of heat is produced.

In order to achieve this result, he could have used a parabolic section. However, he does not adopt this solution. Instead he prefers to generate the reflective surface step by step, forming it out of flat segments, each at barely a different angle to the next, so that all the incident rays are reflected in the same point (the focus). It is therefore not a case of either a circle or a parabola, but of a polygon with countless sides.



Reflection of solar rays on a hemispheric mirror and a polygonal mirror. Leonardo da Vinci. ca. 1503–1505. *Codex Arundel*. British Library, London, Arundel MS 263, fol. 84v–88r. Reprint: Pedretti. 1998. Il *Codice Arundel 263*. Florence: Giunti

Fig. 1. Reflection of solar rays on a hemispheric mirror and a polygonal mirror. Leonardo da Vinci. ca. 1503–1505. *Codex Arundel*. British Library, London, Arundel MS 263, fol. 84v–88r. Reprint: Pedretti. 1998. Il *Codice Arundel 263*. Florence: Giunti

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13_Galluzzi_Autoren_01

The sheets dating from 1507–08, and particularly those from 1513–15, shed light on the reasons that led Leonardo to renounce parabolic mirrors (despite being perfectly aware that in that type of mirror the rays are all reflected in the same point), instead preferring to opt for circle arcs of modest curvature, or for surfaces with multiple faceting. On sheet 1093r (ca.1513–14) of the *Codex Atlanticus*, Leonardo sketches a compass to draw some parabolas mechanically. On another sheet of the same codex (fol. 87r), he recommends using a parabolic rib to create a burning mirror able to smelt metals. Leonardo sought to identify viable solutions for constructing high-performance burning mirrors. He was aware that giving a precise parabolic shape to material objects of a considerable size was extremely difficult. He therefore tended toward solutions that made it possible to produce high-performance mirrors with variable curvatures, according to the desired range, using mechanical procedures (Fig. 2).

Here we can once again observe a somewhat reticent approach, suggested by his desire to protect solutions that offered glimpses of alluring prospects, first and foremost, on a military level. It is no coincidence that in a sheet of studies on burning mirrors (*Codex Arundel*, fol. 279v [P 145r]) focusing on the problem of the focal distance, Leonardo mentions Archimedes and the damage inflicted in 212 BC upon the Roman fleet by his mirrors. This famous episode highlighted the strategic importance of long-range burning mirrors, which Archimedes must have used, given that the enemy ships could not have been right up against the walls of Syracuse

Fig. 2. Leonardo's method to establish the desired focal length of burning mirrors. Leonardo da Vinci. ca. 1513. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 751a–v. Reprint: 1973–1975. Il Codice Atlantico Vol. 9. Florence: Giunti

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13_Galluzzi_Autoren_02

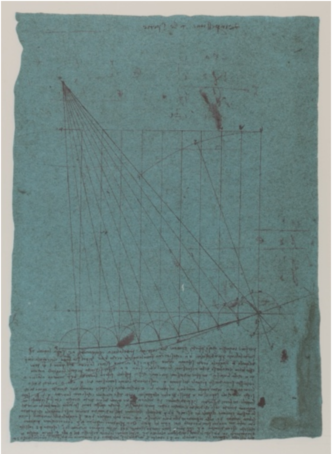

Fig. 2. Leonardo's method to establish the desired focal length of burning mirrors. Leonardo da Vinci. ca. 1513. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 751a–v. Reprint: 1973–1975. Il Codice Atlantico Vol. 9. Florence: Giunti

Industrial applications appeared equally attractive: with the burning mirror "one can make any cauldron in a dye-works boil and with this fisheries will be heated, so there will always be boiling water" (*Codex Atlanticus*, fol. 1036a-v). And elsewhere: "It will make mortar without wood" (*Paris MS G*, fol. 74v).

The hope of tangible benefits becomes apparent in the more advanced phase of his studies on caustics, carried out in Rome between 1513 and 1515. Leonardo undertakes to define an effective method for creating surfaces with curvatures suitable for producing the "condensation" of the sun's rays in a single point. Curvatures whose profile varies according to the focal distances and even to the angles at which the mirror is exposed to the sunlight. The complex geometrical demonstrations make it possible to reconstruct the solution that Leonardo was developing. He establishes the point at which he wants the reflected rays to converge. He then geometrically constructs the section of a reflective surface with the desired focal range. In other words, he overturns the traditional method, according to which, assuming a given curvature of the mirror, the area was identified in which the reflected rays converged. As in the sheets of the *Codex Arundel*, he resorts here to a series of mini-segments, which generate an almost curved profile, from which the sun's rays are reflected in the point established previously.

It is worth highlighting the similarity between the method developed by Leonardo to shape the mirror and the "exhaustion" method conceived by Archimedes to square the circle, resulting in a regular polygon with a number of sides that could tend toward infinity.

Despite moving away from the rigor of ancient and medieval geometrical optics, the solution of the mini-segments offered Leonardo practical advantages that led him to consider it preferable. Once again he does not hesitate to bend mathematical reasoning to the requirements of the processes of constructing high-performance and variable-range burning mirrors.

However, Leonardo’s mind was never restricted entirely to a single perspective, upheld alone against all others. The revival of the old prospect of working circular section mirrors with a minimum curvature provides an eloquent example of his “cyclical” method of working. He was inspired to consider it once again by the method he developed—causing a conic body to rotate on two cogs of different diameter at either end—for drawing arcs of minimal curvature (*Paris MS G*, fol. 45r). By increasing the length of the cone, it becomes possible to describe circles of a huge diameter, from which to extract almost flat arcs to be used as ribs for the construction of long-range burning mirrors. However, the revival of the old theory was not destined to take root: it was soon put away to await future “resurrections.”

In technical terms, the problems that Leonardo had to tackle when developing the “template” for long-range mirrors were considerable. During his time in Rome, Leonardo devoted himself to this problem, examining alternative solutions, each of which was subjected to experimental tests.

During this final phase—recorded primarily on numerous sheets in *Paris MS G*—the mirrors formed by segments of silver-plated copper, soldered using burning mirrors and then reinforced with ribs to give them added rigidity, return to the fore. The priority of the construction concerns led Leonardo to focus his attention on the machines for soldering the mirror’s segments (fol. 74v) (Fig. 3) and for drawing their profiles (fol. 70v), on the construction of templates to be modelled on robust brick supports (fol. 74v) and on the design of complex devices to ensure the perfect profiling of the mirror (fol. 47v).

Fig. 3. Brick profiler for burning mirrors. Leonardo da Vinci. ca. 1515. *Paris MS G*. Institut de France, Paris, fol. 74v. Reprint: Marinoni. 1989. I Manoscritti dell’Institut de France: MS G. Florence: Giunti

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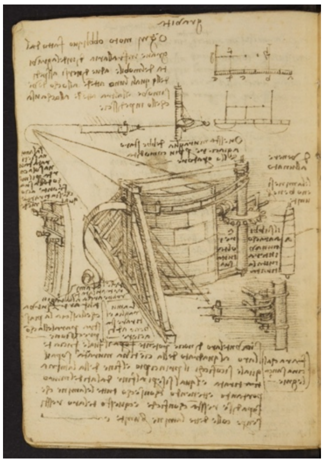

Fig. 3. Brick profiler for burning mirrors. Leonardo da Vinci. ca. 1515. *Paris MS G*. Institut de France, Paris, fol. 74v. Reprint: Marinoni. 1989. I Manoscritti dell’Institut de France: MS G. Florence: Giunti

In the continuous alternation of approaches and working methods observed during Leonardo’s long association with the science and technology of burning mirrors, a tension emerges that, by the beginning of the 16th century, seemed to have stabilized: a stubborn effort to assimilate classical and medieval sources; theoretical and experimental verification of the operative usability of the laws established by the authors of mathematical tradition; commitment to ambitious plans to bend their abstract formulations to the practical needs of architects, without sacrificing the rigor of the proofs.

Leonardo’s sheets on burning mirrors feature numerous examples of this continuous and non-linear interference between theory and practice. One of the most suggestive is provided by a sheet of the *Codex Atlanticus* dating to 1513 (fol. 1036a-v). While he was in a state of excitement regarding the huge benefits that his mirrors promised to generate, a key question occupies the mind of Leonardo: “I wonder whether the pyramid condenses to reduce this power to a single point and, if it becomes heavier than air, what supports it?” The work bench packed with tools and models and the noisy chatting of assistants disappeared from his mind upon the sudden emergence of a crucial philosophical dilemma. The massive production of heat that, according to his calculations, his mirrors promised to generate depended on the "condensation" of infinite solar rays in a single point. Given that condensation implies an increase in density, and thus in specific weight, he sensed a potential conflict with the Aristotelian theory of the elements. By all converging in one point, the rays would form a body heavier than the air. How could the latter support the heavily condensed tip of the burning pyramid?

It is difficult to find a more eloquent example of how, during his later years, Leonardo remained alien to the traditional separation of natural philosophy from mathematical research and experimental practice. No one else at the time would have dared to establish such a direct connection between the outcomes of experimental activities and geometric research into burning mirrors, on the one hand, and an essential question of natural philosophy regarding the general conception of nature, on the other. Here, as in countless other cases, Leonardo's mind shows itself ready to grasp the deepest secrets of the universe in the most ordinary operations of nature and man.

This essay was first published in *Leonardo da Vinci: The Design of the World*, 1452–1519, Skira Editore 2015, 261–270 and is published here with the kind permission of Skira Editore.

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Fasciculus medicinae

Alessandro Nova

The *Fasciculus medicinae* is a compilation of short treatises that had long been attributed to Johannes Ketham, a German-speaking physician (77 □) (Fig. 1).

Fig. 1. Ketham, Johannes de. 1500. *Fasciculus medicinae. Similitudo complexionum & elementorum*. Venice: Johannes and Gregorius de Gregoriis, sheet c2v–c3r (77 □) Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3898

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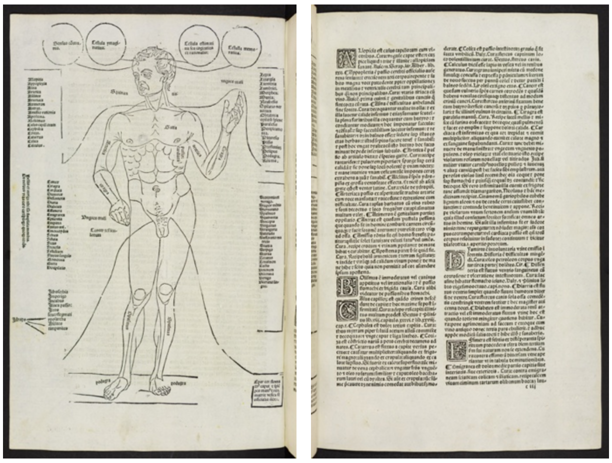

Fig. 1. Ketham, Johannes de. 1500. *Fasciculus medicinae. Similitudo complexionum & elementorum*. Venice: Johannes and Gregorius de Gregoriis, sheet c2v–c3r (77 □) Staatsbibliothek zu Berlin – Preußischer Kulturbesitz. Shelfmark: 4° Inc 3898

Karl Sudhoff, the doyen of medical history, identified him in his facsimile edition titled *Der Fasciculus medicinae des Johannes de Ketham Alemannus* (Milan 1923) as Johannes von Kirchheim, professor at the medical faculty of the University of Vienna between 1455 and 1470.

The format of the first edition in Latin, published in Venice on July 26, 1491, by the brothers Giovanni and Gregorio de' Gregori, is impressive (43 x 29 cm), but the work consists of only two folders with eight folios, 32 pages in all. The name Ketham is absent from the book's incipit, though it is mentioned in the colophon, where one reads: "Finis fasciculi medicine Iohannis de Ketham. Revisus per georgium de monferrato Artium et medicine doctorem qui insuper apposuit titulum auctoritates et loca plura" (End of the *Fasciculus medicinae* by John of Ketham. Revised by George of Monferrato, doctor of the arts and medicine who moreover added the title, authorities and various passages).

According to the most recent scholarship, these facts indicate that Ketham would not have been the main author of the publication but rather the owner of the manuscript that served as the basis for the printing, enriched by the important corrections introduced by the physician Giorgio Ferrari da Monferrato. Ferrari revised the text *(revisus per*), gave the edition a title (*Fasciculus medicinae*), and introduced into the text numerous references to *auctoritates* and the relevant passages.

A vernacular version prepared by Sebastiano Manilio Romano was printed by the same publishers in 1494 (more precisely, on February 5, 1494, *more veneto* [according to the Venetian calendar which began on March 25]). Reduced in size by about a third (to 30.4 x 20.6 cm), this edition also offered readers the first printed translation of the *Anatomia* by Mondino de' Liucci (Liuzzi or Luzzi), the great physician from Bologna who wrote the authoritative text (1316) for academic discourse on anatomy in the late Middle Ages. The dimensions of the vernacular edition (1494), which were also adopted for the second Latin edition (1495), were handier than those of the first edition. Moreover, the two texts were enriched by a splendid iconographic apparatus: four additional woodcuts of high quality were added to the six woodcuts in the 1491 printing, which were themselves corrected and improved for this new edition.

Both products were very successful, as evidenced by numerous reprints. The vernacular edition (1494) was republished twice in Venice, again by the de' Gregori brothers, in 1508 and 1523, and once in Milan in 1509. In addition, there are editions in Castilian published in Zaragoza (1494, *Compendio della salud humana*), Burgos and Pamplona (1495, *Epilogo en Medicina y cirurgia*), and then in Seville in 1517.The success of the Spanish editions of 1494 and 1495 may have prompted the de' Gregori brothers to prepare a second edition in Latin, addressed to an international audience. The 1495 work then gained a frontispiece, while the incipit takes up the title chosen in 1491 by Giorgio Ferrari for the entire collection, with the inclusion of Ketham's name.

This is how the myth of the *Fasciculus*'s author came about. Until the edition of 1491, Ketham's name appeared only in the colophon, as nothing more than a transcription of the colophon used as an antigraph. But now he is presented as the author of the collection: "*Incipit fasciculus medicine compositus per excellentissimum ac medicine doctorem: dominum Ioannem de Ketham Alemanum* [sic]." The second Latin edition was also so well received by the public that it was more frequently reprinted than the vernacular translation. Reprints appeared in 1500, 1501, 1513, and 1522—all of them in the workshop of the de' Gregori brothers, with the exception of the edition published in Antwerp in 1512.

To understand the nature and structure of the collection, as well as the function of the ten illustrations in the first vernacular edition (1494), which were then included in the second edition in Latin (1495), it is helpful read the text of the colophon:

> These are the things contained in this most worthy volume of medicine in the vernacular: in which are treated the following things for the health of the human body: / The manner of judging urine by its colors of all the infirmities of the human body described in pictures. / The manner of taking blood and under what planets. / The figure of man as it is placed under the influence of its own planet. / The figure of the matrix drawn according to nature. / Advice about the plague by Master Piero da Tusignano. / The anatomy of Master Mondino explained from limb to limb, / The power of certain herbs according to Pliny and Albertus Magnus: and many others who have written [on these topics]. (Queste sono le cose contenute in questo Dignissimo Fasciculo di medicina Vulgare: in el qua / le si contiene le sotoscripte cosse per sanita del corpo humano: / El modo de iudicar la urina per li soi colori de tute le infermita del corpo humano scrito in figura. / El modo di trazer el sangue e sotto a che pianeto. / La figura del huomo come le [l'è] sotto posto a li pianeti. / La figura della matrice trata dal natural. / El consiglio per la peste de Maestro piero da Tusignano. / La anathomia de Maestro mondino dechiarata de membro in membro, / Virtu d'alcune herbe secondo Plinio e Alberto Magno: e molti altri che hanno scrito.)

The list clearly illustrates the character of the work as a collection of texts, consisting of short treatises or excerpts of treatises, preceded by full-page illustrated "frontispices." The 52 folios are not numbered but rather arranged in fascicles marked with the letters *a* through *i*.

The first woodcut (sheet a1r) depicts Piero da Montagnana—who was not a physician but a grammarian, philosopher, and bibliophile from Padua—surrounded by the books of his study, among which the *Naturalis historia* (52 □) by Pliny the Elder occupies a privileged place. At Pliny's feet, three patients are gathered, embodying different social groups: a boy, an old woman with a forlorn gaze, and a half-sleeping man in a melancholy pose, all carrying a container of urine that they want to show to the physician. The reverse of the same leaf (sheet a1v), by contrast, depicts a group of elegant physicians debating in a semipublic setting. While the portrait of Montagnana extols theoretical study in a private library, the second image highlights the role of the physician in society, illustrated by a father accompanied by his son who are both handing their urine containers to the figures in robes. The third page (sheet a2r) is decorated with a woodcut depicting a geometric urine wheel. In its center we can read the following words framed by a circle: "Questo e [è] il modo di giudicare le urine pel colore de esse" (Thus urine is judged by its color).

Three aspects need to be emphasized here: a) As we know from the *Codex Madrid*, Leonardo possessed not only the *fassciculu medjcine latino* but also a copy of Bartolomeo Montagnana's *De orina* (also in Latin) (4 □); b) Since the portrait of Piero da Montagnana and the uroscopic consultation are images added in 1494, the wheel diagram in a larger format opened the series of woodcuts in the first Latin edition (1491); c) Finally, the colophon of the new edition in the vernacular informs us that the subject of this writing is depicted "*in Figura*," which underlines the power and function of these most beautiful woodcuts in the reception of the work. At the end of the treatise "*in Figura*" the volume opens to sheet a2v with the following words:

> It begins the most worthy volume on medicine in the vernacular, which treats of all the infirmities of the human body & the anatomy of the same: & [comprising] many other tracts compiled by various excellent physicians with authority and approved texts: & especially the exposition of the color of the urines, and the judgment of the same. (Incomincia el dignissimo Fasiculo de Medicina in Volgare el quale tracta de tute le infirmitate del corpo Humano & de la Anotomia de quello: & multi altri Tractati composti per diversi Excelentissimi [sic] Doctori con auctorita e Testi provadi: & prima la exposition del colore delle Vrine e iudicio de quelle.)

The treatise on urine is followed by treatises on bones and veins with an encomium to phlebotomy (bloodletting) in the context of astrology and the signs of the zodiac. This is the longest text of the volume, illustrated with no less than four woodcuts: *Uomo dei salassi* (sheet a4r), *Uomo dello zodiaco* (sheet b2r), *Uomo delle vene* (sheet b2v), *Uomo delle ferite* (sheet b6v). On these pages, simple questions about specific health problems alternate with simple remedies and recipes.

The fourth of the treatises collected in the volume is the chapter on the female reproductive organs, preceded by a full-page woodcut (sheet d1r) illustrating the "lifelike depiction of the female body" (the woman shown is pregnant in the 1491 edition, but not pregnant in the 1494 and 1495 editions). At the end of the treatise on female reproductive organs, another full-page woodcut (sheet e2r), added in 1494, shows a physician taking the pulse of a plague patient who is lying on a bed without a shirt. This woodcut introduces the book in the collection on the favorite subject of Piero Curialti da Tossignano, another protagonist of the medical schools of the 14th century, who probably died in 1404:

> Here begins the venerable teaching on the plague compiled by the highly renowned doctor of arts and medicine, Master Piero Tausignano. (Incomincia el dignissimo

> consiglio per la peste composto dal famosissimo doctor delle arti & di medicina Maestro Piero Tausignano.)

The wonderful woodcut showing the dissection of a human body before the eyes of a young physician at the lectern, (sheet F2v) (the woodcut was added in the second edition and is considered one of the masterpieces of 15th-century graphic art) is followed by these words:

> Here begins the anatomy or dissection of the human body: written and compiled by the highly renowned and eminent doctor of arts and medicine, Master Mundino. (Commincia [sic] la Anathomia overo dissectione del corpo humano: composta e compilata per el famosissimo & eximio doctore del arte & de medicina maestro Mundino.)

Finally, the last page of the book is devoted to “certi secreti de herbe” (certain secrets of herbs), selected with reference to the authoritative texts of Pliny the Elder and Albertus Magnus.

The title “fassciculu medicine latino” in the list of Florentine books of 1503–1504 (*Codex Madrid II*, fol. 2v) (4 ◻) leads us to the richly stocked bookshelf of medicine and anatomy in Leonardo’s library. Having grown up in the workshop of Verrocchio and but a few steps from that of the Pollaiuolo brothers, Leonardo had been interested in anatomy since his youth. Yet while his teachers and contemporaries intensively studied only those fields that seemed the most useful to them for their professional activity, such as myology, Leonardo devoted himself with extreme rigor to analyzing the human body in all its complexity, eventually cultivating relationships with the best physicians of the time over many years (the Marliani family, Marcantonio della Torre) (69 ◻; 87 ◻).

The list of books Leonardo owned between 1490 and 1495 (*Codex Atlanticus*, fol. 559r (3 ◻), confirms his early interest in medicine: among the 40 titles on the list are two copies of the *Chirurgia* by Guy de Chauliac (ca. 1298–1368), as well as a *De chiroma(n)tia*, a *Çibaldone* (perhaps the *libro tertio de lo Almansore called Cibaldone*), and a *Della conservation della sanità*, which may be identified as a *Tractato utilissimo circa la conservatione de la sanitade* (Milan 1481) by the Sienese physician Ugo Benzi.

The list of the years 1503–1504 (*Codex Madrid II*, fol. 2v–3v (4 ◻), by contrast, reflects a very different story, since scientific and philosophical culture plays a much greater role here than in the library of a few years earlier. The work of Guy de Chauliac is mentioned only once (“guidone in cerusia”), but Leonardo had in the meantime acquired volumes of great diagnostic value, such as the *Tractatus de urinarum iudiciis* (Padua 1487) by Bartolomeo Montagnana (listed as *montagnana de orina*), even if other texts are difficult to identify because of the generic nature of their titles.

The *De chiromantia*, the *Conservation di sanità*, and the *Çibaldone* (already included in the previous list) are now joined by the *De natura umana*, perhaps the work of Antonio Zeno published with this title in Venice in 1491 and a *Libro di notomia*, which could refer to the five books of the *Anatomice sive historia corporis humani* (Venice 1498 and 1502) by Alessandro Benedetti or to one of the many editions of the *Anathomia Mundini*. In addition, Leonardo possessed a *libro di medicine di cavalli*, which could have consisted of a collection of texts such as Giordano Ruffo’s treatise on farriery, published in several editions.

In any case, the pearl of Leonardo’s medical library was the *Fasciculus medicinae*, entered in the *Codex Madrid II* as “Latin,” that is, probably, as an exemplar of the first luxury edition of 1491: rare (in Italy it is found only in the Fondazione Cini, in addition to the two copies held by the Vatican Library), expensive, large, and richly illustrated with six full-page woodcuts. To be honest, it cannot be determined with absolute certainty whether Leonardo was in possession of the *de luxe* edition printed in Latin in 1491 or the less wieldy edition published in 1495, also printed in Latin. But a drawing of the Tree of the Veins, now in Windsor (W 12597), suggests that he consulted both, probably along with the Italian translation. Unfortunately, the dating of the sheet is disputed, but as has often been noted, the similarities between the sketch and the woodcut are remarkable, and the work can be taken to document Leonardo's knowledge—still approximate—of medicine and especially anatomy toward the end of the 15th century.

The early 16th century, in contrast, was characterized by rapid growth fostered by the exchange with a great physician from the University of Pavia, the Veronese Marcantonio Della Torre. By overcoming the tension between the analytical word and the synthetic image, their collaboration in practice made it possible to recognize what had tended to divide, and continued to divide, medical theory. As Vasari wrote in the *Vite*:

> [Leonardo] afterwards devoted himself … to the anatomy of the human being, assisted in this task by Marc'Antonio della Torre, whom Leonardo in turn helped. Della Torre was then lecturing and writing in Pavia on the subject, and he was one of the first to begin using the teachings of Galen to illustrate the matters of medicine and to shed true light on anatomy, which until then had been shrouded in the darknesses of ignorance.

Translated from the German by Michael Thomas Taylor

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The Eye – Portal to the World and Dark Chamber: Leonardo’s Optics

Wolfgang Lefèvre

> *The eye whereby the beauty of the world is reflected by beholders is of such excellence that whoso consents to its loss deprives himself of the representation of all the works of nature. Because we can see these things owing to our eyes the soul is content to stay imprisoned in the human body; for through the eyes all the various things of nature are represented to the soul. Who loses his eyes leaves his soul in a dark prison without hope of ever again seeing the sun, light of all the world; and how many there are to whom the darkness of night is hateful though it is of but short duration; what would they do if such darkness were to be their companion for life.*
>
> Francesco Melzi after Leonardo da Vinci
>
> *Codex Urbinas Latinus 1270*, fol. 13r (Translation in McMahon 1956)

This eulogy to the eye and the sense of sight appears in Leonardo’s *Treatise on Painting*. The treatise is a comprehensive project for a book on the multiple and diverse aspects of painting but, like many of his other works and projects, Leonardo never completed it. After his death it was compiled from various notes in his literary estate, and then published (Life and Legacy D □; Life and Legacy F □).

In fact, this eulogy to the sense of sight should be seen in the context of the art of painting as shown in Leonardo’s own works and those of the early Renaissance. The statement that the sense of seeing is capable of representing all the works of Nature can be interpreted as a justification for the emergent technique of perspectival representation in painting, which was just reaching its first peak at the time. It claimed to represent reality by trying to portray it in images as it appeared to the eye. In other words, it tried to represent the world on the picture base (wood panel or fresco) as it was represented in and through the eye. The intended match between the representations of the image and the eye is not an illusory effect: it is a matter of imparting to the perspectival image the realism ascribed to the eye’s perception of the world.

Florence in the 15th century, where Leonardo began his artistic career, was among the centers—perhaps the most important one—of this new style of painting. It was here at the beginning of the century that an experiment by the architect Filippo Brunelleschi (1377–1446) demonstrated the constructability of perfect representations in central perspective. It was here, too, that the painter Masaccio (1401–1428) created an exemplary realization of the new painting style in a fresco in the Florentine church *Santa Maria Novella*. Florence was also the city where the humanist and architect Leon Battista Alberti (1404–1472) lived and worked. Alberti’s treatise on the art of painting (*De pictura*, 1435–36) expounded the geometrical and optical principles which formed the basis for the geometrical construction of perspectival representation, known as the *costruzione legittima.*

Leonardo became acquainted with the techniques of this style of painting in the 1470s as an apprentice in the workshop of the sculptor and painter Andrea del Verrocchio (1435–1488). Verrocchio’s workshop was a renowned training center for young artists of the time—besides Leonardo, they included Sandro Botticelli, Lorenzo di Credi, and Pietro Perugino, who later became Raphael’s master teacher. In this workshop the trainee artists not only acquired the different technical skills but also learned about the related theories. For perspectival representation this meant Alberti's *costruzione legittima* and the geometrical optics, or ray optics, in the Euclidean tradition that it was based on.

This ray optics and its application in perspective construction were the starting point for Leonardo's lifelong occupation with and intensive study of optical phenomena, including the vision of the human eye. At this point we need a few key remarks about the ray optics derived from Euclid. It assumes that light rays travel in straight lines and teaches how they can be reflected in mirrors (catoptrics) or refracted in transitioning to a denser medium (dioptrics). It also assumes that light rays travel to/from the eye to/from every point of the shining or illuminated objects in the field of vision, i.e. it assumes a visual cone formed by the bundled light rays with its peak located at/in the eye. As Alberti showed, the intersections of this bundle of light rays with a vertical plane slicing through this cone yields a perspectival view of the field of vision. This meant that creating a correct perspectival view consisted of making a geometrical construction of this intersection (Alberti's *costruzione legittima*).

It is typical of Leonardo's way of examining this and other problematic areas—practical mechanics, the flow of water, the anatomy of the human body, etc.—that he refused to be satisfied with the practical aspects. He always simultaneously asked critical questions about the conceptual or, if they existed, theoretical preconditions and assumptions. In the case of optics, the *practical* application of the *costruzione legittima* had some irritating effects—for example, distortions in size in the case of wide-angled visual cones –, which had to be corrected by painters according to specific rules and, in principle, judged by eye. Leonardo critically noted these and other practical shortcomings of this geometrical construction method—for example, the assumption that the beholders view with one eye only, and the fixing of the exact location from which they had to view a picture to enjoy the perspectival representation to the full. But this did not induce Leonardo to question the method of construction as a whole. In fact, very few artists actually constructed the perspectival representation of a subject according to the elaborate geometrical procedure proposed by Alberti and codified later by Piero della Francesca (?–1492) und Albrecht Dürer (1471–1528). Artists preferred easier construction methods or mechanical means such as the perspectograph, which Leonardo was familiar with, as a small sketch shows (Fig. 1). In one of his notebooks (*Codex Arundel*, fol. 62r), Leonardo for his part made the distinction between the practical or the artistic and the "natural" perspective, using the terms *prospettiva* *accidentale* and *prospettiva naturale.* With this he hinted at the theoretical insufficiency of the ray optics underlying this construction.

Fig. 1. Leonardo da Vinci. 1478–1482. *Perspective frame*. Codex Atlanticus. Biblioteca Ambrosiana, Milan, fol. 5r (83 ◻). Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti

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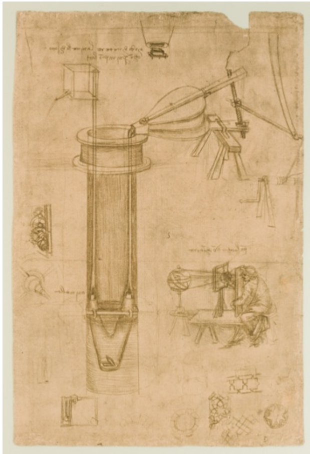

Fig. 1. Leonardo da Vinci. 1478–1482. Perspective frame. *Codex Atlanticus*. Biblioteca Ambrosiana, Milan, fol. 5r (83 ◻). Reprint: 1973–1975. Il Codice Atlantico Vol. 1. Florence: Giunti

The ray optics as handed down from Euclid and adopted by Alberti left open the question of the nature of light rays and their direction (to or from the eye?). Another open question was the process of vision in the eye itself. Euclidian optics ignored the question of the physical nature of light and the physiology of vision and the related anatomy of the eye. This was, indeed, deliberately excluded, for these questions were the subject of rival theoretical traditions in antiquity as well as in the Middle Ages in both the Arab countries and the West. Regarding the nature of light rays, two aspects were controversial. First, the question of whether light rays emanate from the objects in the field of vision and are then received by the eye (the theory of *intromission* of rays propagated by the ancient atomists and the Arab mathematician Ali al-Hasan ibn al-Haitham, also known by the Latin name Alhazen, ca. 965–1040), or whether the eye perceives objects because it sends out rays toward them (the theory of *emission* of rays advanced by Stoics and Platonists in antiquity and the Arab/Persian philosopher Avicenna, 980–1037). The second controversial question concerned what was really communicated to the eye—images (*idola*) of objects, as the ancient atomists thought, or isolated stimuli through the individual light rays, as the majority of medieval mathematicians and natural philosophers assumed.

Leonardo's pursuit of these questions ignored by ray optics, which had little to do with the construction of perspectival images, testifies to a theoretical curiosity that went beyond questions of painterly practice and to a degree of familiarity with these controversial theoretical traditions. It is not clear how much he owed this particular knowledge to his contacts with other artists and humanists in Verrocchio's workshop or elsewhere in the cultural metropolis of Florence and later in Milan, and how much to the relevant literature—such as the influential medieval treatises on optics by Roger Bacon (1220–1292), Witelo (ca. 1235–?) or Johannes Peckham (ca. 1230–1292). According to the list in *Codex Madrid II*, fol. 2v (72 ◻), he certainly owned a copy of Peckham's *Perspectiva communis* (1278), one of the standard works on optics that had helped to make Alhazen's theory of optics known and influential in the West. How much could Leonardo, with his limited—in fact, self-taught—knowledge of Latin, glean from the ancient and medieval literature on optics known in his time?

Leonardo began by following the dominant doctrines. In relation to the different alternatives for the direction in which light rays spread, this meant emission theory. The phenomena and arguments that finally convinced him of the correctness of the alternative theory—that of intromission of light rays—came partly from the literature. For example, the objection that the sight of the starry sky must exceed the eye's emission capacity had already appeared in

Alhazen’s work. Other objections by Leonardo could definitely be due to his own observations and reflections—such as the objection that illuminated colored objects cast a matching colored gleam on neighboring objects. His idea of invoking the projection of the outside world into the interior of a *camera obscura* as an argument against emission theory was certainly original. (We shall return below to the *camera obscura* in connection with Leonardo’s thoughts on the anatomy of the eye.)

It was difficult to solve the other open question in relation to the light rays, the question of whether these rays transmit isolated light impulses or *idola* of the objects. If they transmitted *idola*, how could it be guaranteed that, in the course of this transmission, all the *idola*, independently of the size of the emitting object, could pass through the pupil and appear in the eye in the correct relative magnitude? And if isolated light impulses were indeed transmitted, how and by what means did they combine in the eye to form the image of the objects? A decision for either one of the alternatives would obviously have consequences for the understanding of anatomy and function of the eye. In any event, in the course of his attempts to understand the anatomy and function of the eye in such a way that the process of seeing would be compatible with the basic principles of ray optics, Leonardo rejected his initial assumption of a transmission of *idola*.

The *camera obscura* played an important role in this—Leonardo used it as a model of the eye (Fig. 2). This is often emphasized, especially because he seems to have been the first person to have spotted this analogy. It is, however, important to take a closer look at which functions of the eye he associated with the *camera obscura* as a model and which he did not, and to note the difficulties he incurred with this model. In the first place, the analogy between the pupil and the small opening in the *camera obscura* through which the light rays entered the interior of the eye and the dark chamber respectively was close at hand. It was also obvious to assume that in both cases the light rays acted according to the principles of ray optics and this meant that both in the eye and in the dark chamber they generated an image of the world outside in which left and right and top and bottom were inverted.

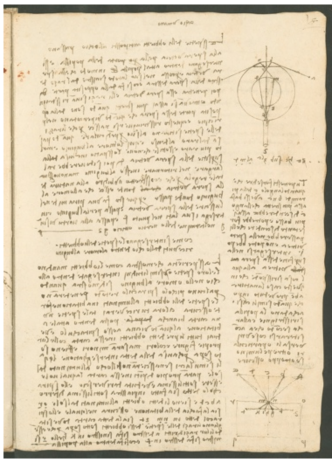

Fig. 2. Leonardo da Vinci. ca. 1508–1509. *Camera obscura*. *Paris MS D*. Institut de France, Paris, fol. 8r (82 □). Reprint: Marinoni. 1986. I Manoscritti dell’Institut de France: MS D. Florence: Giunti

Fig. 2. Leonardo da Vinci. ca. 1508–1509. *Camera obscura*. *Paris MS D*. Institut de France, Paris, fol. 8r (82 □). Reprint: Marinoni. 1986. I Manoscritti dell’Institut de France: MS D. Florence: Giunti

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This inversion confronted Leonardo with major problems. First, he could not imagine that the brain—or more precisely, the *impressiva*, the organ in the brain responsible for sensual perception adopted at the time—was capable of reverting it. It was therefore an imperative assumption for him that this reversion already had to occur in the eye before the brain processed the image. And this assumption led to the anatomical conviction that there must be a lens in the eye, or more exactly, in the vitreous humor (*corpus vitreum*), that reverted the inverted image back to the original. The *camera obscura* analogy might suggest that this lens in the vitreous humor projected the reinverted image onto the retina. But this was contradicted by the contemporary anatomical view that the optic nerve projected into the vitreous humor like a pier. In other words, in order for the reverted image to reach the *impressiva*, the lens Leonardo assumed to exist in the vitreous humor, had to project it onto the protruding end of the optic nerve. Another consequence of this anatomical assumption was that when they entered the eye the light rays already had to be refracted in such a way that they were not scattered over the whole vitreous chamber but reached the inner lens. Leonardo attributed this task to the cornea in front of the pupil rather than to the lens behind the pupil (*lens crystallina*), which he usually ignored completely.

As hypothetical as these anatomical assumptions have been as hypothetical was necessarily every assumption about the exact ray path inside the eye. It is not surprising that Leonardo's notes contain various sketches of this ray path. Over 10 such sketches can be found in a late manuscript, the Paris *Manuscript D*, dated to 1508–09, which is exclusively concerned with questions of optics and can be taken as Leonardo's final version of the optical process (Fig. 2). This background makes it easier to understand why Leonardo, who is known to have attended anatomical dissections of corpses and even to have performed them himself, finally, in 1509, performed a dissection of a bovine eye to determine the exact position and form of the postulated lens in the vitreous humor. (This experiment failed for technical reasons because the fluid vitreous humor could not be fixed.)

Thanks to the idea of the *camera obscura* as a model of the human eye, Leonardo could assert that the eye receives light rays from objects and does not emit them to objects. Also 'thanks' to this idea, though, he had to struggle with the tricky problem of inverted images. To solve this problem, he invented anatomical structures that prevented the field of vision from being projected onto the retina. In other words, a *camera obscura* without a projection plane served as his model of the eye, that is, a *camera obscura* without exactly the part by which Johannes Kepler (1571–1630) decoded the process of seeing a century later—"*ut pictura, ita visio"*: the view is like the image (= the projection on the retina). We should add that in Leonardo's time the c*amera obscura* did not exist as we know it today. Until the second half of the 16th century only astronomers made practical use of optical projections for solar observations. Usually they were created on the floor of a room with a small hole in the darkened window. Devices equipped with lenses and mirrors such as in Kepler's day did not yet exist. Ironically, Leonardo's envisaged eye, taken conversely as a model of the *camera obscura*, had lenses like the later devices.

Until around 50 years ago, Leonardo's lifelong occupation with questions of optics was barely recognized by the otherwise exhaustive literature about his life and work, and far from thoroughly researched. One usually only saw his many untenable hypotheses and registered the lack of approaches to moving beyond the ancient and medieval theory of vision and of the eye, and toward developments that would later lead to the optics of the modern age. This overlooked the fact that Leonardo's investigations of optical phenomena differ from those of most of his predecessors and contemporaries not only in terms of their breadth, inventiveness and open-mindedness but also and above all in terms of their strictly empirical mindset. This thoroughly modern approach to theoretical questions was not least due to the "dilettantism" of an artist-engineer who was satisfied neither by purely theoretical answers nor by purely pragmatic ones. The admirable endeavors of this man without a school or university education to be up to date also theoretically are not least documented by his astonishingly rich library which is reconstructed and made widely accessible by the exhibitions to mark the 500th anniversary of his death, in Florence, Stanford, and now here in Berlin.

Translated from the German by Karen Margolis

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Rethinking Leonardo for the Anthropocene

Pietro Daniel Omodeo

Modern man should be a synthesis of those traits that are ... presumed as national characteristics: the American engineer, the German philosopher, the French politician, recreating so to speak, the Italian man of the Renaissance, a modern type of Leonardo da Vinci who has become a mass-man or collective man while nevertheless maintaining his strong personality and originality as an individual
Antonio Gramsci
Letters from Prison (Columbia University Press, 2011, vol. 2, 194–95)

In this letter to his wife "Julca," penned in 1932 while he was imprisoned in Fascist Italy, antifascist political intellectual Antonio Gramsci (1891–1937) reflected on how to best raise their children and the type of person that they wanted them to become. He reminded his wife how she had considered naming their second son "Leo" instead of Delio, a name that, as an abbreviation for "Leonardo," now seemed like a good omen. Gramsci described Leonardo da Vinci as a symbol of the practical, theoretical, and ethical-political aspects of his epoch. He thought that the Renaissance already bore all features of modernity, without, however, reaching the "division of intellectual labor" that would cleave a rift between different groups of intellectuals and professionals. Engineers, philosophers, politicians, and—one might add—scientists and researchers, often seem to represent two divergent and incommensurable "cultures," according to Charles Percy Snow's popularization of the notion that the methodologies of the *Naturwissenschaften* (natural sciences) and *Geisteswissenschaften* (humanities) are fundamentally irreconcilable. At the same time, the necessity of bridging the gap between nature and culture, humanities and natural science, has never seemed so pressing.

Understanding their interrelations is important for developing adequate intellectual and practical responses to the contemporary challenges of environmental politics, in which geological and historical time overlap. Rethinking Leonardo da Vinci today means taking a privileged historical and historiographical point of view on our technological, scientific age, the state of humanity today, and the future of our planet, because all of these topics are entangled with one another in the work of the Renaissance artist and scientist. The unity of intellect and craft that Leonardo embodies is exemplary of what Jürgen Renn recently called the "ergosphere" when discussing one of the most important factors in the current manmade technological transformation of the Earth: human labor. It should be placed at the center of thought on technological development, particularly in its interactions with forms of knowledge and epistemic ideals and practices.

The aesthetic grace of Leonardo da Vinci's depictions of nature—the backgrounds of his master paintings (17 □) and the meticulous drawings in the preserved codices—has a significance that goes beyond mere visual pleasure. The Renaissance's naturalism was enormously important for the development of a practice-oriented scientific culture rooted in empirical observation. A broad range of research on the practical foundations of science has highlighted this insight, research that spans from Marxist sociology to newer scholarship on practical knowledge in the history of art and science. For instance, in his historical-materialist work on the Renaissance, Lucio Lombardo Radice wrote that the demands of realism in painting and sculpture necessitated deeper knowledge of anatomy and perspective. This forced artists in Italian workshops in the 15th century to engage with the study and practice of medicine and mathematics. In turn, they made their own contributions to these disciplines, thus furthering their development. Mechanics, ballistics, military architecture and hydraulics, geology, and landscape engineering were the fields that Leonardo excelled in, and he did so without ever abstracting science from its practical, transformative context. At the same time, his practice was always guided by the steady hand of certain, rational knowledge. “Those who are in love with practice without knowledge,” he remarked, “are like the sailor who gets into a ship without rudder or compass and who never can be certain where he is going.”

Leonardo described knowledge—of which mathematics is the prime example of utmost certainty—with a military metaphor: “Science is the captain, and practice the soldiers.” The comparison was not simply grasped out of thin air. It derived directly from the artist-scientist’s own biography, life experience, and decisions having served ambitious men like Ludovico il Moro (Ludovico Sforza) and unscrupulous condottieri like the Duke of Valentinois, Cesare Borgia, who provided the model for Machiavelli’s “Prince.” In his famous letter to the Duke of Milan, Ludovico Sforza, in which he laid out his resume (Fig. 1), Leonardo almost exclusively focused on presenting his skills in military technology, while relegating to the margins those applicable to civilian ends. As for his artistic projects, they only received cursory mention. Leonardo promised Ludovico il Moro that he would reveal to the duke his “secrets,” which, he boasted, were superior to “common” inventions. He was talking about bridges, scaling ladders, cannons, methods capable of “destroying every fortress or other stronghold,” mortars, covered vehicles, techniques for sea battles, ways of constructing subterranean passages without making noise. “In short,” he concluded, “as the variety of circumstances dictate, I will make an infinite number of items for attack and defence” (67 □). Compared with all of this weaponry, the things that Leonardo could have accomplished in times of peace seemed hardly worth the mention. He limited himself to general remarks about being able to construct “both public and private buildings,” conduct “water from one place to another,” and sculpt statues, in particular a bronze horse that would “be to the immortal glory and eternal honour of the auspicious memory … of the illustrious house of Sforza” (68 □).

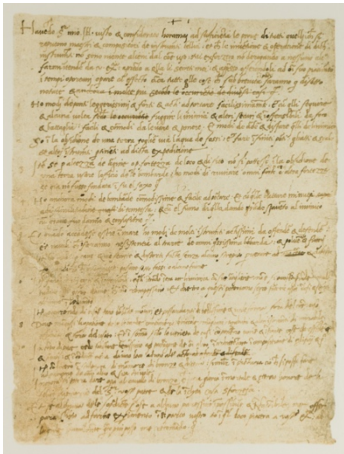

Fig. 1. Leonardo da Vinci. ca. 1482. *“Job application” to Ludovico Sforza*. Codex Atlanticus. Biblioteca Ambrosiana, Milan, fol. 1082r (67 □). Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti

Fig. 1. Leonardo da Vinci. ca. 1482. *“Job application” to Ludovico Sforza*. Codex Atlanticus. Biblioteca Ambrosiana, Milan, fol. 1082r (67 □). Reprint: 1973–1975. Il Codice Atlantico Vol. 12. Florence: Giunti

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Gramsci’s reading of the work that Leonardo had performed in the service of force and power took a different direction than the praise contained in the introductory quote above. In a letter to his sister-in-law Tatiana Schucht, he interpreted it as a sign of Italian intellectuals’ deep-rooted tendency to sway between opportunism and cosmopolitanism, writing: “it was a matter of indifference to Leonardo whether he sold the designs for the fortifications of Florence to Duke Valentino. The Communes were thus a particularistic [*sindacalista*] state, which did not succeed in transcending this phase and becoming an integral State as Machiavelli vainly urged.” Eugenio Garin (1909–2004), historian of the philosophical culture of the Renaissance, offered a more conciliatory, if also more abstract, assessment of Leonardo’s accomplishments, writing that he had “above all the merit of having lived both the arduous and wonderful history of his time in heroic harmony.” Cesare Borgia’s patronage of Leonardo came at a time when the prince was at the height of his political powers: he ruled over central Italy, which he, in the name of his father, Pope Alexander VI, ravaged with fire and fury from Urbino to Romagna to Tuscany. Did this patronage cause a scandal? What about Leonardo’s work for a foreign king who got him to spend the last years of his life in France? In his willingness to serve the powerful without many qualms, Leonardo himself displayed a certain Machiavellianism.

Indeed, Leonardo knew Machiavelli. The two Tuscans frequented one another during the most heated period of the Italian Wars in the late 15th century. Perhaps they first met in Urbino, just after Borgia took it over. More than just one of the most important military cities of the time, Urbino was also a center of cultural-scientific blossoming: Baldassare Castiglione later penned his codification of court etiquette there. Moreover, it was home to the school of Federico Commandino, which produced research on mathematics and engaged with the work of Archimedes; and Guidobaldo del Monte, one of Galileo’s early benefactors, authored notable studies on mechanics as one of the Commandino school’s members.

Leonardo did his most intensive work for Borgia between July and September 1502. In a letter granting him safe passage in order to inspect the fortifications, Borgia commanded that Leonardo be provided “with as many men as he requisitions” and called him “our most eminent and well-beloved familial friend, the architect and engineer general Leonardo Vinci.” Some documentation of this debated period of Leonardo’s life is preserved in a small codex held as *Paris MS L.* It begins with a remark about Leonardo’s search for a translation of the work of Archimedes, the great mathematician and military engineer of antiquity. Alongside various technical projects, it contains drawings of fortifications and notes about mapping Borgia’s territory. The notes allow us to reconstruct Leonardo’s travels from Urbino, where he inspected the city’s defenses, to Cesena and Porto Cesenatico, and finally western Tuscany.

Later biographies—and particularly those whose authors who were close to the House of Medici, such as Vasari’s *Lives*—left out Leonardo’s compromising relationship with Borgia. But considering the fact that others, beginning with Machiavelli himself, saw Borgia’s undertakings as the Renaissance’s greatest attempt to overcome Italy’s fragmentation and realize a political system that transcended the peninsula’s many city-states and communes, it is possible to interpret Leonardo’s work for Borgia in a way that differs both from its suppression in the Medici-friendly narratives as well as from Gramsci’s criticism of it. For historians of science, Leonardo’s emphasis on military technology in his letter to Ludovico il Moro might be read as an index of the primacy of the political over the economic in his work, if we assume (again drawing on Machiavelli) that the Italian wars of the 15th century were an—albeit failed—attempt at state building.

The *socio-economic roots* of modern science have been uncovered by historians, and particularly those of the “externalist” school of the history of science who, in the 1930s and 1940s, drew on Soviet scholar Boris Hessen (1893–1936), the politically-minded neo-positivist Edgar Zilsel (1891–1944), and the Polish “Frankfurter” Henryk Grossmann (1881–

1950). In this light, Leonardo's case invites us to focus on the political dimensions of science in the Renaissance. At the same time, it is worth noting that Leonardo lived during an age when the logic of profit had not yet come to dominate everything in society, including war, thus leaving open considerable room for the relative autonomy of different spheres of activity.

Leonardo's work in cartography has particular significance in this regard. Leonardo never separated it from military ends. The *Map of Imola* (Fig. 2) is a precise representation of the northernmost outpost of the provinces under Borgia's control.

Fig. 2. Leonardo da Vinci. 1502. *A map of Imola*. Royal Library, Windsor. Inv.: RCIN 912284. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / akg-images / Album

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Fig. 2. Leonardo da Vinci. 1502. *A map of Imola*. Royal Library, Windsor. Inv.: RCIN 912284. Royal Collection Trust, Windsor © Her Majesty Queen Elizabeth II 2021 / akg-images / Album

In his maps of papal territories and central Italy, he included not only the conquered regions, but also the targets of expansion. His maps of the Chiana Valley, for instance, including the map held by the Royal Library of Windsor (12278r), concentrate on an area that gained in geopolitical significance after the Aretine rebellion against Florentine rule in June 1502. But Leonardo also had grand ideas about reshaping the territory and was thus highly interested in studying the basin of the Chiani River that runs through the region. This coincidence of Leonardo's occupation with both cartography and hydrology precluded a clear distinction between military mapmaking and civilian waterworks. He dreamt of redirecting the Chiani—the path of which had been changed by humans since Etruscan and Roman antiquity—in order to increase the volume of the Arno river in Florence. The downsides of this titanic undertaking have gained even literary fame thanks to Roger Masters's *Fortune Is a River* (1998), which tells of the project, pursued in the context of the lengthy war between Pisa and Florence, to divert the Arno to drain Pisa while turning the Florence of Amerigo Vespucci into a Mediterranean port.

In this context, Leonardo's meeting with the Florentine official Machiavelli is a much-discussed topic, dealt with by Patrick Boucheron in a subtle essay:

> Leonardo hoped to contribute to peace and prosperity by changing the course of the river and taming water power through the canal. ... The canal, Leonardo writes, 'will make the countryside fertile, and Prato, Pistoia, and Pisa, as well as Florence, will rake in around 200,000 ducats a year.' ... Ultimately, though, it is the war that justifies the construction of the canal; after all, politics is a short-lived business. As Machiavelli does not tire of emphasizing to the Signoria of Florence, it is primarily a matter of conquering Pisa without siege or onslaught. Once peace has returned, the canal should bring prosperity to Florence and its former rival alike, and in this way reconcile the two. This the people owe solely to the sovereign neutrality of technology. (Boucheron 2008, p. 96)

Leonardo’s beautiful drawings of the Arno Valley (18 □) (Fig. 3) and flowing rivers, which accentuate the image of Leonardo as an artist and philosopher of variety, are not separable from his work as a hydraulic engineer. The advice he gave Ludovico il Moro on how to improve the canal system in Milan is one prominent example. Another is when, anticipating a possible invasion, Leonardo proposed that the Republic of Venice construct mobile barriers along the Isonzo River. “My most illustrious lords,” Leonardo wrote in March or April 1500 to the government of Venice, “as I have perceived that the Turks cannot invade Italy by any part of the mainland without crossing the river Isonzo, and although I know that it is not possible to devise any means of protection which shall endure for any length of time, I cannot refrain from bringing to your notice the fact that a small number of men aided by this river might do the work of many, seeing that where these rivers … [section missing].” For those same Turks, Leonardo would later design a futuristic bridge to cross the Bosporus, connecting Asia and Europe; the draft can be found in the codex *Paris MS L* from Leonardo’s time working for Borgia (113 □). Was he imagining a U-turn in technology and politics when he promised his services to the Sultan after having been in the employment of the Serenissima, the Most Serene Republic of Venice? Indeed, that there was a political motivation behind Leonardo’s work as a technical advisor cannot be denied. Similarly undeniable is how his work in landscape engineering and his creation of what then must have seemed fantastic inventions presage the technical sublime of Americanism and the Anthropocene, while his plan to construct mobile barriers around Venice anticipates today’s experimental electromechanical modules to protect the city from high tides, known under the pseudo-Biblical acronym MOSE (from the Italian: MOdulo Sperimentale Elettromeccanico). Leonardo’s century also witnessed less spectacular, but deeply innovative largescale public works projects, such as the construction of irrigation canals that radically altered Italy’s landscape, particularly in Lombardy under the Sforzas, but also in Venice and Tuscany.

Fig. 3. Leonardo da Vinci. August 5, 1473. *Landscape of the Arno Valley*. Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 8 P r (18 □) akg-images / De Agostini Picture Lib. / R. Bardazzi

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Fig. 3. Leonardo da Vinci. August 5, 1473. *Landscape of the Arno Valley*. Gabinetto Disegni e Stampe degli Uffizi, Florence. Inv.: 8 P r (18 □) akg-images / De Agostini Picture Lib. / R. Bardazzi

Leonardo’s work in geology was closely intertwined with these developments. A century ago, Giuseppe De Lorenzo described Leonardo’s engagement for the Florentine Republic in a way that has passed the test of time. In his book *Leonardo da Vinci e la geologia*, he writes of the period between 1503 and 1506: “And so, while he was in the city painting *The Battle of Anghiari* and the *Mona Lisa* and advising where to best place Michelangelo’s *David*, on the countryside, he was devising his flying machines and flights from Monte Cerere and designing hydraulic works for the Duke of Valentinois [Cesar Borgia] and the canalization of the Arno. At the same time, he was absorbed in viewing fossils (59 □) and geological terrain, which brought him back to ruminations on the transformation of the Arno Valley and the ancient geological relations between the Apennines and the adjacent seas." Of all the preserved manuscripts, the *Codex Leicester* is the one that is most helpful for exploring the relationship between Leonardo's interests in hydraulics and geology. It contains "paleographic" reflections about the Arno Valley and its formation by the river's sediment deposits (*Codex Leicester*, fol. 9r). These reflections fit into his studies on water management. Leonardo analyzed the distribution of fossil shells in order to chart how the coastline looked in the distant past (CR Essay Schneider). Thus, he researched the history of the Earth by observing fossils; he grappled with hydrography, the complex composition of soils, and the formation of mountains and plains through fluvial processes. Water appeared to him as our world's primary instrument of transformation ("Water is the driving force of nature," we read in *Paris MS K*, fol. 2r). It erodes mountains and moves minerals. Over the long term, it creates global imbalances between land and water that rearrange landscapes and cause disasters. Pierre Duhem (1861–1916), a major French scholar of Leonardo's work and reception, saw in his treatment of such "petits mouvements de la terre"—small tremors of the Earth combined with shifts in their cosmological centers of gravity—an anticipation of the theory of terrestrial motion developed by Nicolaus Copernicus (1473–1543) soon thereafter. The cosmic perspective aligned with Leonardo's fascination with the Earth in its historical and spatial, geological and astronomic aspects, as expressed in the *Codex Atlanticus* (fol. 365v): "The knowledge of past times and of the places on the earth is both an ornament and nutriment to the human mind."

For Leonardo, the world is a coherent whole. Man is everything's measure—or, as the neo-Platonists of the 15th-century "Accademia Fiorentina" would have said, the *nexus rerum universalis*, the universal nexus of all things. Donning his anatomist's hat (Manuscript A, fol. 55v), Leonardo reflected on the microcosm, a topic beloved by Marsilio Ficino (1433–1499) and other admirers of Plato's *Timaeus*:

> Man has been called by the ancients a lesser world, and indeed the term is rightly applied, seeing that if man is compounded of earth, water, air and fire, this body of the earth is the same; and as man has within himself bones as a stay and framework for the flesh, so the world has the rocks which are the supports of the earth; as man has within him a pool of blood wherein the lungs as he breathes expand and contract, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world; as from the said pool of blood proceed the veins which spread out their branches throughout the human body, in just the same manner the ocean fills the body of the earth with an infinite number of veins of water. In this body of the earth there is lacking, however; the sinews, and these are absent because sinews are created for the purpose of movement, and as the world is perpetually stable within itself no movement ever takes place there, and in the absence of any movement the sinews are not necessary; but in all other things man and the world show a great resemblance. (McCurdy 1923, 93–94)

In sum, Leonardo's geoanthropology grew out of his belief in human faculties and his desire to change the world through science and technology, both of which he placed at the service of politics. This was part of a philosophical naturalism that viewed man and Earth, life and the cosmos as cohering, connected beings, both in a material sense and in a structural-functional sense. In particular, Leonardo's holistic conception of the inseparable unity of nature and culture can offer a fruitful perspective on today's pressing questions about the identity of the *anthropos* as a being that defines a geological age. So, too, can his a priori rejection of the division between eye and hand, theory and practice. His practice had at least two aspects: the *poiesis* of technological invention and the *praxis* of collective action

In the 20th century, Machiavelli's masterwork, *The Prince*, was read as a political theory of collective subjectivity, because political action in contemporary society can only take the form of mass action. Similarly, the artist, inventor, and scientist, the ideal unity of which was embodied by Leonardo, can and must be understood in a non-individualist sense. A statement by Gramsci, this time from his *Prison Notebooks*, provides one such reading:

> One might say that the typical unitary process of reality is found here in the experimental activity of the scientist, which is the first model of dialectical mediation between man and nature, and the elementary historical cell through which man puts himself into relation with nature by means of technology, knows her and dominates her … . Scientific experiment is the first cell of the new method of production, of the new form of active union of man and nature. (XI §34, 446)

The scientist of Leonardo's type is the molecular agent of macroscopic, technological, and scientific transformations at the intersection of the ergosphere, technosphere, and the many other spheres of the system in which we live.

Translated from the German by Adam Bresnahan. Funded by the Department of Philosophy and Cultural Heritage at Ca' Foscari University in Venice, the European Research Council for the Consolidator Grant *EarlyModernCosmology* (Horizon 2020, GA: 725883), and the Italian Ministry of University and Research for the FARE project EarlyGeoPraxis (R184WNSTWH).

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Diamonds and Glass: A Conversation in the Workshop of Leonardo Research

A “Dialogo vinciano” between Antonio Becchi and Jürgen Renn

Since a Commission has been set up to oversee a National Edition of Leonardo’s writings, and in light of the imminent foundation and generous endowment of an Institute of Leonardo Studies that appears to hold a monopoly on any research directly pertaining to the person and work of da Vinci, mere mortals might well believe they may do no more than wander the atrium or among the columns of the peristyle, never to penetrate the hallowed shadows of the sanctum.

Luigi Gramatica, 1919

JR – Antonio, you have made the *Codices Forster* a focus of your research. By way of introduction, could you briefly put them in the context of Leonardo’s other manuscripts?

AB – Gladly. The *Codices Forster* (ca. 1487–1505) are held by the Victoria & Albert Museum in London, and comprise three volumes, two of which, *Forster II–III*, are very small, only slightly larger than a credit card (ca. 95 x 70 mm and 90 x 65 mm), while the third, *Forster I*, is about twice that size (ca. 140 x 100 mm). They consist of five notebooks (*Forster I* and *II* contain two, *Forster III* only one) devoted to many different subjects, as Leonardo’s notebooks generally are. They are named after John Forster (1812–1876), a renowned biographer—of his friend Charles Dickens (1812–1870), among others—and collector, who came into possession of these manuscripts then bequeathed them, along with the greater part of his library and art collection, to the South Kensington Museum in London, which was later renamed the Victoria & Albert Museum (V&A).

JR – What exactly is meant by “Codex”?

AB – We must bear in mind that the term Codex is used in a very broad sense in relation to Leonardo’s work, namely to mean volumes of various size in which drawings and manuscripts are compiled. Or “were compiled” I should more rightly say in the case of the *Codex Atlanticus, Codex Arundel,* and *Codex Leicester*, since the sheets in those are no longer “bound” but presented meanwhile as separate entities. However, the other Codices are individual volumes. Among them number some smaller books, seven particularly small (sextodecimo) manuscripts of similar scope, the *Codices Forster II–III*, and the *Manuscripts H*, *I*, *K*, *L*, *M* held by the *Institut de France* (IdF) in Paris.

On account of their size, these manuscripts are often referred to as pocket notebooks, ideal for use when not at a desk—on the road, the street, or the construction site. The two notebooks that make up *Codex Forster I*, together with similarly sized manuscripts (the *Manuscripts E*, *F*, *G* in octavo format, held by the IdF), can be defined as pocket-sized, too, and in any case lend themselves to mobile use. Larger sheets and books, on the other hand, were obviously designed for the execution of drawings and writings in more comfortable settings.

It is often remarked that these small manuscripts feature notes taken outdoors as well as interventions made at a desk. The drawing or writing medium used and the typical characteristics of the drawings on paper attest to these various uses of them.

JR – How many Leonardo Codices are there in total, and what do we know about the way they were compiled? (117 □)

AB – At present we know of 22 Codices: the *Codex Atlanticus* (Biblioteca Ambrosiana, Milan), the *Codex Trivulziano* (Biblioteca Trivulziana, Milan), the *Codex on the Flight of Birds* (Biblioteca Reale, Turin), the *Codices Madrid* (Biblioteca Nacional de España, Madrid, 2 volumes), the *Codex Arundel* (British Library, London), the *Codices Forster* (V&A, London, 3 volumes), the *Manuscripts A–M* (IdF, Paris, 12 volumes), and, finally, the *Codex Leicester* (Bill & Melinda Gates Foundation, Seattle).

However, the total count could vary if, say, we were to exclude the *Codex on the Flight of Birds*, because, before Guglielmo Libri (1802–1869) stole and sold it and, moreover, tore out some folio pages and sold them as separate items, it was an appendix to *Manuscript B* held by the IdF; or, similarly, if we were to take into account the *Manuscripts 2184* (also known as *Complément du manuscrit B*, formerly belonging to *Manuscript B*) and *2185* (also known as *Complément du manuscrit A*, formerly belonging to *Manuscript A*), both now held by the IdF. These were once known as the *Codices Ashburnham 1875/1* and *1875/2* (or *Codices Ashburnham I* and *II*), and consist of sheets which Guglielmo Libri took from the Leonardo codices held by the same IdF and then sold to Bertram Ashburnham, 4th Earl of Ashburnham (1797–1878). It was only after the latter's death that the sheets were returned to France and reintegrated into the IdF collections (Fig. 1), although not into the manuscripts they'd been part of prior to the theft (which is why they are referred to as *Complément du manuscrit A* etc.).

Fig. 1. Giunti Editore facsimiles of the manuscripts *A-M*, *Ashburnham 1875/1– 2,* and the *Forster-Codices.* Library of the Max Planck Institute for the History of Science. Photo: Lukas Külper and Marvin Müller

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Fig. 1. Giunti Editore facsimiles of the manuscripts *A-M*, *Ashburnham 1875/1–2,* and the *Forster-Codices.* Library of the Max Planck Institute for the History of Science. Photo: Lukas Külper and Marvin Müller

The Album in which the sheets were formerly compiled and which is now held by the Royal Collection at Windsor likewise could be considered a Leonardo Codex. Its binding bears the title "Drawings by Leonardo da Vinci restored by Pompeo Leoni" ("Disegni di Leonardo da Vinci restaurati da Pompeo Leoni"). This Album is closely related to the *Codex Atlanticus*, the binding of which announces "Drawings of Machines and Secret Arts and Other Things by Leonardo da Vinci compiled by Pompeo Leoni" ("Disegni di machine et delle arti secreti et altre cose di Leonardo da Vinci racolti da Pompeo Leoni"). The bindings of the *Codex Atlanticus* and the Windsor Album are preserved to this day in their respective locations, the Biblioteca Ambrosiana and Windsor Castle. The Windsor Album, like the three Codices we have already discussed, was once disbound and its sheets are now treated as independent entities.

JR – I find it remarkable that two notional codices—the *Codices Ashburnham*—were created only in the 19th century. What about the other Codices? Which period do they date from?

AB – Most of the compilations renowned today do not date from Leonardo's time, but were assembled later in the form of Albums and Codices. The *Codex Atlanticus* and the Windsor Album were the result of Pompeo Leoni's work of selection and "restoration." In later years, Leoni was heavily criticized for his treatment of Leonardo's papers. However, we should not lose sight of the fact that compiling albums of drawings was common practice among artists, collectors, and art dealers. Leoni stood in this tradition, which was to flourish for several centuries more. Greater sensitivity and respect can be found in the work of Leonardo's favorite pupil Giovanni Francesco Melzi (1491/1493–1567), to whom the master had bequeathed his papers. Melzi read and studied them in preparation for the book on painting (Life and Legacy D □).

JR – What role did Melzi play in the later dissemination of Leonardo's legacy of manuscripts?

AB – Each sheet and each Codex has its own unique history, comprising twists and turns more or less tortuous and obscure. Yet there is *one* way station, *one* turning point that may plausibly be said to connect them all: the Villa of the Melzi family in Vaprio d'Adda near Milan. It was in this residence that Giovanni Francesco Melzi stored and explored Leonardo's personal estate after returning home from France, to where he had followed his master and stood by him until the end of his days (on May 2nd, 1519).

When Melzi himself died in 1567, his heirs did not take care of this legacy and its dispersal began only a few years later, which is how Pompeo Leoni and other collectors came to gain possession of several manuscripts and drawings. From this point on, Leonardo's sheets were up for grabs, so to speak, subject to barter, selection, fragmentation, and reorganization. The Codices we know today are the result of this checkered history and, unfortunately, we often lack the elements necessary to reconstruct in detail the stages and methods of their composition, although in some cases the connections are clear. For example, certain sheets preserved in Windsor perfectly closed obvious gaps in the *Codex Atlanticus*. Carlo Pedretti (1928–2018), one of the leading experts on Leonardo, published important analyses of such counterparts and reconstruction.

JR – Digital reproductions have of course now vastly improved the efficacy of this task of reconstruction. How do Leonardo's working methods add to the difficulties of reconstruction?

AB – The interpretation of these thousands of sheets dating from the late 1570s to Leonardo's final months is difficult indeed, and demands caution and discernment. Research into the fascinating maze of papers left to us by Leonardo is complicated by the fact that he often returned to an earlier phase of his reflections, adding notes to previously annotated pages. He also copied notes and drawings years after making them or, again at intervals of years, added prefaces to works that he would have liked to make clean copy of, and probably would have had put into print, but which in any event remained unfinished, even in cases where progress had been substantial.

JR – But there is one exception, even so.

AB – Yes, a very few drawings do feature in a book published in Leonardo's lifetime: the *Divina proportione* (1509) (75 □) by Luca Pacioli (ca. 1447–1517). Pacioli himself in the work *De viribus quantitatis* attests to his friend's contribution, praising his "exquisite and extremely delicate representations of all Platonic and regular coherent mathematical solids, which cannot be better done in perspective drawing …, produced and formed by that incomparable left hand" ("supraeme et legiadrissime figure de tutti li platonici et mathematici corpi regulare et dependenti che in prospectivo disegno non è possibile al mondo farli meglio … facte et formate per quella ineffabile senistra mano") (L. Pacioli, *De viribus quantitatis*, 1997, p. 21). The drawings by Leonardo are related to the published illustrations (Pacioli 1509), as well as to the images found in two manuscripts of the *De divina proportione* now held in Geneva (Bibliothèque de Genève) and Milan (Biblioteca Ambrosiana) (86 □).

JR – Let's end this digression and return to the *Codices Forster*. When did these specific Codices catch your attention, and why?

AB – Like anyone involved in the history of science, art, and architecture, I have always regarded Leonardo and his work with admiration and interest (A. Becchi, *Q.XVI. Leonardo, Galileo e il caso Baldi*, 2004; *Naufragi di terra e di mare. Da Leonardo da Vinci a Theodor Mommsen*, 2017), but my research on the *Codices Forster* is more recent and was provoked by a detail in the *Codex Forster II*, namely a page of drawings illustrating a mechanical problem. These drawings differ in small but significant ways from similar images in other Leonardo manuscripts. I therefore decided to investigate the reasons for these peculiarities as well as the contexts in which the drawings were made.

This topic lies within a field of research that I have been pursuing for years, with you and other friends and colleagues at the Max Planck Institute for the History of Science (MPIWG). Our projects lead us, after all, to daily examine manuscripts and printed texts from the Middle Ages, the Renaissance, and the Early Modern period, which address very similar problems to those previously tackled by Leonardo. This alone is an indication of the broad-ranging interests of Leonardo—a man who was accustomed to drawing the future.

Let's not forget, however, that the fascination exerted by Leonardo's works can have an almost hypnotic effect, too, and some of the peculiarities I'll relate regarding the history of the *Codices Forster* must be put down to this, at least in part.

JR – You've whet my curiosity, but first, allow me to ask, how you began your research into these Codices and what led you to enter the hallowed halls of Leonardo research?

AB – In hallowed halls, it isn't done to raise one's voice too loudly. But allow me, Jürgen, to begin by thanking the colleagues at our library, at the Museo Galileo (Florence), at the Biblioteca Leonardiana (Vinci), at the Institut de France (Paris), at the Warburg Institute and at the Victoria & Albert Museum (London), without whose expertise and generosity my research would not have been possible.

I wanted simply to reconstruct the "biography" of these manuscripts and soon came across a surprising detail. While for all other Leonardo Codices there are documents, testimonies, and clues that allow us to clarify or, at the least, to roughly estimate their provenance, the *Codices Forster* seem to have appeared out of the blue in the second half of the 19th century. Quite unlike the *Codices Madrid*, for example, which were "rediscovered" in the mid-1960s, but had been known of for some time already, and had even been catalogued.

There are many traces of the odyssey undergone by Leonardo's manuscripts, some 4,100 sheets in total, in the immediate aftermath of Giovanni Francesco Melzi's demise. When it comes to the history of the *Codices Forster*, however, the information is so scarce that no one has ever managed to fill in this yawning gap: three centuries of silence. The dearth of information raises questions galore. It's rather strange, for example, given that the three Codices together comprise hundreds of sheets, that no one ever described or even mentioned them before the second half of the 19th century.

How could they have remained hidden for so long—where, by whom, and why, we wonder? And once they did emerge from oblivion, why were they not publicized far and wide as a sensational discovery, and sold for a fortune? This mysterious provenance makes the *Codices Forster* unique in the panorama of da Vinci's manuscripts and confronts scholars with questions that remain unanswered to this day.

JR – Leonardo's drawings and manuscripts are the subject of a monumental publishing project, the so-called National Edition, conducted under the auspices of the National da Vinci Commission (CNV, *Commissione Nazionale Vinciana*), and thanks to which facsimile volumes, transcriptions, and critical apparatus are now available to scholars. For this, we historians can be truly grateful. In 1919 Luigi Gramatica spoke of the fact that "mere mortals" might think they'd never be allowed to penetrate the hallowed shadows of the sanctum of Leonardo research (p. 11)—a sentiment that the very impressive National Edition may well have reinforced. You nevertheless did penetrate those hallowed halls, Antonio. What did you find there? Doesn't this esteemed publication by leading Leonardo experts offer any reliable information on the origins of the *Codices Forster*?

AB – There are only two "monographs" devoted to the *Codices Forster*, and both have been included in the National Edition published by Leonardo experts. Firstly, between 1930 and 1936 the Royal Vinci Commission (RCV, *Reale Commissione Nazionale Vinciana*) took it upon itself to publish the *Codices Forster* in several volumes, with an introduction by Enrico Carusi. Then, after World War II, the Commission for the National Edition of Leonardo da Vinci's Manuscripts and Drawings (better known as the *Commissione Nazionale Vinciana*, CNV) critically examined the publication of the *Corpus Vincianum* and launched a long and fruitful collaboration with the Giunti publishing house (the volumes being originally published by Giunti Barbèra, which is now Giunti Editore). This all happened within the framework of the said National Edition, namely the serial compilation and publication of all of Leonardo da Vinci's manuscripts and drawings under the auspices of the CNV - an undertaking that served in essence to perpetuate and update the original RCV project.

JR – But what does the National Edition tell us about the *Codices Forster*?

AB – Patience! I'm coming to that now. Augusto Marinoni (1911–1997), a renowned and esteemed scholar who had begun studying Leonardo's writings in the mid to late 1930s, worked between 1970 and 1992 on transcribing and critically editing those Codices to be included in the National Edition (in parentheses, here, the dates of the edition of the facsimiles and transcriptions): *Codex Atlanticus* (1973–80), *Codex on the Flight of Birds* (1976), the *Manuscripts A–M* held by the IdF (1986–90), and the *Codices Forster* (1992).

He was also responsible for revising the edition of the *Codices Madrid* (1974) prepared by Ladislao Reti (1901–1973), who died before completion of the project. This international edition was not entrusted to the CNV, but Giunti Barbèra obtained the rights for Italy. In 1980 Marinoni published an edition of the *Codex Trivulziano* with Arcadia/Electa. This manuscript, transcribed by Anna Maria Brizio (1902–1982) and then revised by Marinoni, became part of the National Edition that same year.

In his introduction to the *Codices Forster*, Marinoni ponders the problem of the three manuscripts' origins:

> We do not know how they arrived in Vienna, but someone wrote [in German] on the half title of Forster I: 'Leonardo da Vinci, the greatest painter / of the Italian school. Born in 1452 / at Vinci, entered as a / war architect into the service of / Duke Valentin Borgia in 1502: and died: 1519.' Then, in the last century, the codices were purchased by Count Edward George Lytton, and upon his death in 1873 were inherited by John

> Forster, who in 1876 bequeathed them to the Victoria & Albert Museum." ("Come giunsero a Vienna non sappiamo, ma sul foglio di guardia del Forster I una mano scrisse: 'Leonardo da Vinci der grösste Maler / aus der italienischer Schule. 1452 zu / Vinci geboren, trat 1502 als / Kriegs Baumeister in die Dienste / Herzogs Valentin Borgia: und starb: 1519'. Furono poi acquistati nel secolo scorso dal conte Edward George Lytton e alla sua morte nel 1873 furono ereditati da John Forster che li lasciò morendo nel 1876 al Victoria & Albert Museum.) (1992, I, p. X)

JR – That sounds pretty straightforward, so what's the problem?

AB – Yes, the problem does appear to be solved, if we take his words at face value: at the least, they offer some clear historical pointers. We note nothing more than a trivial transcription error, a mistaken declension: "aus der italienischer Schule" instead of "aus der italienischen Schule."

JR – Thanks to your eagle eye!

AB – In this case it really does come down to detective work. So, to continue: Edward George Lytton had purchased the Codices—in Vienna, Marinoni appears to suggest—then bequeathed them to John Forster in 1873, who in turn donated them to the V&A in 1876.

It's easy to imagine the influence Marinoni's words had on later scholars, some of whom simply echoed them without checking their reliability, because they do sound unequivocal, at first. The National Edition has the highest standing and the CNV plays the role of ultimate guarantor, as does the "High Patronage of the President of the Italian Republic" ("Alto Patronato del Presidente della Repubblica Italiana") mentioned in the first pages of the National Edition of the *Codices Forster*. Which is why these volumes are generally treated as an encyclopedic reference work, a source of sound and authoritative information.

JR – But quite a number of newer works have appeared since then, particularly in 2019, the Year of Leonardo (1519–2019). For example, what does the catalogue of the major exhibition organized at the Louvre on the occasion of the fifth centenary of Leonardo's death (*Léonard de Vinci*, October 24, 2019–February 24, 2020) have to say about our topic?

AB – Louis Frank, chief conservator in the Department of Graphic Arts at the Louvre, and one of the two curators of the said catalogue and exhibition, writes there in a chapter entirely devoted to Leonardo's manuscripts:

> *Codices Fo[r]ster*. The three manuscripts *Fo[r]ster I, II, and III* came to the Victoria and Albert [Museum], at the time the South Kensington Museum, in 1876, as a gift from John Fo[r]ster, who is said to have received them as a gift from Lord Edward George Lytton, who is said to have acquired them himself in Vienna. They bear markings attributed to Pompeo Leoni. Their history in the interim is not known. (*Codices Foster.* Les trois manuscrits *Foster I, II et III* entrèrent au Victoria and Albert, alors South Kensington Museum, en 1876, par donation de John Foster, lequel les aurait reçus en don de lord Edward George Lytton, qui les aurait lui-même achetés à Vienne. Ils portent des marques que l'on attribue à Pompeo Leoni. Leur historique intermédiaire n'est pas connu.) (L. Frank, *L'océan des manuscrits*, in V. Delieuvin & L. Frank (eds.), *Léonard de Vinci*, 2019, p. 182)

Frank's statements thus correspond roughly to those Marinoni made 27 years earlier. Yet, once again, no primary sources are cited.

JR – So, is that which Marinoni wrote correct, in your opinion?

AB – Unfortunately not; in fact, it is misleading. The strangest thing is that his statements can be refuted, at least in part, by research that takes no more than ten minutes. Therefore, let's analyze this brief passage just as Leonardo would have tackled his anatomical inquiries, which is to say, by paying acute and unbiased attention to the facts.

JR – Very well. Perhaps I can support this anatomical analysis by asking some simple questions: Is there any documentary proof at all that Edward George Lytton (Edward George Bulwer-Lytton, 1803–1873) purchased Leonardo's Codices?

AB – No, none at all.

JR – Could the transfer of the manuscripts have taken place in 1873, when Edward George Lytton died?

AB – There is no evidence to support this supposition, and certainly Marinoni does not provide any.

JR – Then is there at least some evidence that the *Codices Forster* were in Vienna prior to and at the time of the alleged purchase?

AB – No, there is not. We could go on indefinitely, Jürgen, but for the sake of brevity I'll go straight to the heart of the matter: original signed documents from the 1860s indicate that it was Robert Lytton (Edward Robert Bulwer-Lytton, 1831–1891) who acquired the Codices, not his father Edward George Lytton; and that Robert Lytton gave them to his friend John Forster before the summer of 1865. This information is readily available, in part in volumes published decades ago but also in more recent works such as Carmen Bambach's brilliant *Leonardo da Vinci Rediscovered* (2019), in which she mentions the acquisition made by Robert Lytton, and adds that "all three Codices Forster volumes reappeared in Vienna early in the nineteenth century." (Bambach 2019, II, 69). Nevertheless, many scholars disregard Robert Lytton's role and instead put blind faith in the National Edition (1992). The latter, however, provides no accurate bibliographic information about the origins of the *Codices Forster*.

JR – So, it seems that the chronology proposed by Marinoni must also be revised. Where, then, did the manuscripts originate and when did Robert Lytton acquire them?

AB – Robert Lytton describes them in a letter of October 4th, 1862, which for the moment provides us with the relevant date *ante quem*. However, we do not know where he bought them—he makes no mention of that in his letter. On the other hand, certain clues to be found among his Lytton family descendants suggest that the purchase may have been made not in Vienna but in Florence.

Other clues derived directly from Robert Lytton's correspondence with his wife Edith Villiers (1841–1936) indicate that the price paid must have been relatively modest. And not only that: Robert Lytton makes clear several times in these letters that he intends to have an expert examine the Codices, which were meanwhile in Forster's hands, in order to verify their "genuineness." In October 1865—being recently wed, first-time father of a newborn child, and somewhat short of money—he even thought about selling them (if they turned out to be genuine); and this, despite the fact that he had already made a gift of them to his friend Forster. His wife put her foot down, however, and persuaded him that this course of action was out of the question.

JR – What was the outcome of the expert appraisal specifically sought by Robert Lytton?

AB – Unfortunately, we don't know at the moment. But it very likely took place at John Forster's house in London. Between 1862 and 1878 no one described the *Codices Forster* publicly in books, journals, or newspapers. This further protracted silence is astonishing, because Leonardo was already long since a legend, carefully cultivated by artists and collectors, and his manuscripts were a precious commodity, even subject at times to theft and manipulation.

JR – Antonio, to return to the question of the Codices' provenance: What do we know about that?

AB – Their provenance is obscure, which itself is most suspicious. The Codices were found or acquired (it is not known where) by an anonymous collector, dealer, or accidental owner, who decided to sell them in great secrecy, without publicizing them, even though this might possibly have been to his benefit—for he'd have been remembered forever as the man who discovered three new Leonardo manuscripts.

JR – Now this really is beginning to sound like a detective story.

AB – Well, this willingness to remain in the shadows does not speak for an honest seller and "clean" goods. As far as we know, Robert Lytton never spoke publicly about the provenance of these manuscripts, and nor did John Forster. Had Lytton perhaps let him in on a secret?

To return to the national edition: what can be said with certainty is that Marinoni gave the impression in these few lines of knowing a story about which he *de facto* knew very little. His readers therefore had good reason to believe all that he subsequently wrote, especially given the publication's good standing; but their confidence was to prove misplaced.

JR – But how did Marinoni reach this conclusion? Which sources did he rely on, when asserting these "facts"?

AB – He very likely trusted secondary sources without carefully checking their reliability, and was influenced in particular by the earlier edition of the *Codices Forster* (1930–1936), in which Enrico Carusi had provided similar information (E. Carusi, *Prefazione*, in *I Codici Forster I-III nel "Victoria and Albert Museum,"* 1936, p. 12).

JR – This could seemingly go on *ad nauseam*: one author copies from another, and he in turn from another. Where does it all end—and what, if anything, lies at its root?

AB – Well, at the root of Marinoni's assumptions and those of many other authors before and after him seems to be the somewhat hasty reading of a passage in one of the most famous publications devoted to Leonardo, namely *The Literary Works of Leonardo da Vinci* (1883), a two-volume opus by the German scholar Jean-Paul Richter, who was then living in London. Beneath his transcription of the note handwritten in German in *Codex Forster I*, Richter noted that: "This volume and the two others now in the Forster Library of the South Kensington Museum, London, were given to Mr Forster by Lord Lytton, who is said to have bought them at Vienna for a low sum" (Richter 1883, II, p. 490).

It is interesting to trace the alchemical shifts undergone by Richter's circumspect claim over the years, from 1883 to 1992. These range from interim versions, each more fanciful than the last, to far later ones, up to the present day. Richter in fact wrote nothing more than "Lord Lytton" and "who is said to have ... ."

JR – And which Lord Lytton was he referring to, do you think? Either way, the statement remains ambivalent.

AB – Exactly. But the only Lord Lytton alive in 1883 was Robert Lytton, whose father had died in 1873; and the only Lord Lytton before 1873 was Edward George (who from 1866 was Lord Lytton of Knebworth). The genealogical ambiguity must have been noticed already in Richter's lifetime, because in the new edition of his work published posthumously in 1939 it is stated that: "[The Codices] were given to Mr. Forster by the Earl of Lytton, who is said to have bought them in Vienna." (Richter 1939, II, p. 409). Robert Lytton was (from 1880) the first Earl of Lytton and this fact alone preempts any confusion with his father.

JR – Are you sure that the father died in 1873?

AB – You sound like Sherlock Holmes, whose heyday this was, incidentally, give or take a year or two. But that Edward George Lytton died in 1873 is beyond any doubt, also because he gave precise instructions in his will regarding the examination of his corpse, so as to preclude any chance of him being buried alive "in a trance."

JR – How reassuring! But to return to the Codices' provenance: Is the idea they were acquired in Vienna to be believed?

AB – It probably stems from two clues that are generally, and perhaps mistakenly, taken at face value. The first is that the diplomatic career of Robert (not Edward George) Lytton included a spell as embassy secretary in Vienna. Later on, from 1876 to 1880, he was Viceroy of India. The second clue is simply that the brief annotation in *Codex Forster I* is written in German.

JR – After all, Lytton, the real Lytton, did have a job in Vienna at the time he acquired the Codices.

AB – Yes, but that's not necessarily the point given that he also often travelled in this period, and stayed several times in Italy too.

JR – And what about the second clue, the note in German? It doesn't suggest Italian provenance.

AB – It would be naïve to take the note in German as proof that the purchase was made in Vienna.

JR – If you say so; but what else might we deduce from it?

AB – It appears to have been copied verbatim from an encyclopedia published some years earlier—in 1837—or almost verbatim, since some lines were omitted: for example, curiously enough, the passage recalling Leonardo's move to France and his death in the residence provided him by Francis I (1494–1547, King of France 1515–1547). In any case, the brief biographical profile accompanying *Codex Forster I* sounds rather strange. It details his birth in Vinci and his relationship with Cesare Borgia, but says nothing about the time he spent in Florence, Milan, Rome, and France.

JR – Who could have penned those lines

AB – There's any number of candidates, in London, Paris, Florence, or wherever. A German-speaking writer would have found the task easier but of course might well have carried it out in a non-German-speaking country. And then, anyone can copy from an encyclopedia, even if unable to speak the language it is written in.

JR – That's certainly true, but does it get us anywhere? Is this where we lose track of the fate of the *Codices Forster*? Was perhaps the note in German meant not to reveal but to conceal their provenance? Didn't you mention that clues from a later date suggest the Codices may have been acquired in Florence? And where would that lead us?

AB – Perhaps in Florence, perhaps not. I just wanted to make clear that there's no reason to associate them categorically with Vienna or any other German-speaking place.

JR – Well, no, but current research still appears to take what Marinoni wrote as its benchmark. You're surely aware of the clear and unequivocal statement made in reference to the *Codices Forster* by Allison Lee Palmer recently, in her book *Leonardo da Vinci. A*

Reference Guide to His Life and Works (2018): “The notebooks originated in an earlier collection gathered by Pompeo Leoni (c. 1531–1608), which was sold to Count Galeazzo Arconati, who donated the collection to the Biblioteca Ambrosiana in Milan in 1637. The books were perhaps stolen and then sold sometime after 1700, when they later reappeared in the estate of John Forster … .” (Allison Lee Palmer 2018, p. 45). Whatever the obscure interim may have entailed, this account of their provenance does seem highly plausible at first glance!

AB – But beware! Those who have more closely examined Arconati’s donation and Leonardo manuscripts once held by the *Biblioteca Ambrosiana* in Milan have found no indication that three Codices resembling the Forster ones were part of the donation or were ever identified among the *Ambrosiana*’s holdings. The *Codex Atlanticus* and 12 manuscripts now in the possession of the IdF were once held there, but they were transferred to Paris in 1796, as a result of the first Italian campaign (1796–1797) and the attendant requisitions ordered by Napoleon Bonaparte. Of these, solely the *Codex Atlanticus* was returned to the Ambrosiana, in 1815. The words of Allison Lee Palmer are, in my view, merely an eloquent illustration of the confusion that still reigns on the topic—and which such reference works unfortunately perpetuate.

JR – Do you think it’s possible that the *Codices Forster* were, at a cautious guess, “pieced together” from disparate sources only in the 19th century? That would in any case explain why their “discovery” was not heralded with a fanfare—because they were not a “discovery” but possibly mere “assemblage.”

AB – That would account for some of their peculiarities.

JR – In any case, this story strongly reminds me of that of the *Codices Ashburnham*, which, as you’ve already said, were “pieced together” by Guglielmo Libri from manuscripts taken from other Leonardo Codices, and then sold to the Earl of Ashburnham; a story that unfolded in the very same era and places of interest to us here. And it’s the story of a notorious, unscrupulous master thief of countless manuscripts and books, who was active in Italy, France, and England. Are we really to believe this is a coincidence? How authentic, then, are the *Codices Forster*? Should the real question be, not “What is the provenance of these Codices?” but “From what sources were they cobbled together?”

AB – The sheets composing the *Codices Forster* are so numerous as to rule out a priori that they were all once part of other, previously known Leonardo Codices, especially as quite accurate descriptions of the latter have survived from earlier periods. Moreover, while some experts believe that the headbands in the *Codices Forster* can be dated to the late 16th or early 17th century, Enrico Carusi maintained in 1939 that they appeared to be relatively recent (E. Carusi, “I manoscritti di Leonardo,” in *Leonardo da Vinci*, 1939, p. 160). These differing verdicts only serve to confirm the importance of further in-depth research into these bindings, so that they may be minutely compared with those of other Leonardo manuscripts. We should be wary of speculation, however, if only to avoid repeating the mistakes of the past. Reconstruction depends on always clearly distinguishing the facts from more or less unfounded flights of fancy.

JR – Can we return once again to the history of the Codices in the 19th century?

AB – For that era, we need not rely on speculation, for we have, among other things, a whole series of original letters to and from Robert Lytton. The fact that he himself was not entirely sure the Codices were genuine and deemed it necessary to have them examined suggests that their provenance was indeed unusual.

JR – Are there, besides this, any other clues that might further our quest for the sources of the manuscripts compiled in the *Codices Forster*? Surely, it must be possible to draw conclusions also from their physical characteristics.

AB – There are telling differences between the originals of the *Codices Forster* and the facsimiles known to us, such as numerous holes in the manuscripts which in the facsimiles look like stains.

JR – But did the indefatigable and meritorious Marinoni not notice such peculiarities or simply not consider them worth mentioning? On what basis then, did the Leonardo scholar work? How reliable is his description of the Codices' characteristics?

AB – I've asked myself these same questions and can name you one example that made me wonder. Marinoni describes "an acronym written exceptionally in red" ("una sigla, scritta eccezionalmente in rosso") in *Codex Forster II* (Marinoni 1992, II, p. VIII). In reality, it is clearly written in black ink.

JR – So what's the explanation? Was Marinoni color blind?

AB – No, the mix-up is evidently due to the fact that Marinoni worked with the facsimile of the *Codices Forster* edition published by the RCV in the 1930s, in which the writing is in red, owing to a printing error. That old edition even contains a note about the error but Marinoni apparently overlooked it, or had already forgotten about it.

JR – Well, that seems to me a most forgivable error!

AB – A forgivable error, but significant nonetheless—depending how you look at it. After all, we are dealing with an obscure history, the fate of manuscripts dispersed over half a millennium, and any physical characteristic may be an important clue to their provenance. The National Edition is the fundament on which research must be able to rely.

JR – And it cannot?

AB – In many respects, it can; but in this case Marinoni seems to have relied in part on the Leonardo edition published 60 years earlier, without bothering to consult the new images that Giunti had produced for these facsimiles.

JR – And what about the originals?

AB – At the very least, Marinoni should have consulted them in order to check some specific details, such as in the case of the error just mentioned. The same goes for Marinoni's description of the quires contained in the *Codices Forster*, which in certain respects, as anyone who takes a close look at the originals and the bindings can see, bears no relation to reality. Yet despite these shortcomings, we must never forget how indebted we all are to Marinoni for the enormous effort he devoted to Leonardo's manuscripts for over 60 years.

JR – Is such an oversight an isolated instance or a sign of a larger, underlying problem?

AB – It is no isolated instance, unfortunately. The National Edition is an extraordinarily important work for which, as I have already said, we can be truly grateful. It's the basis of countless studies of Leonardo and its slogan is: "Leonardo's codices and drawings have been reproduced in facsimiles that are completely identical to the originals." ("I codici e i disegni di Leonardo sono stati riprodotti in facsimile perfettamente identici agli originali"). But this is not wholly true. Last year, for example, I used the copy in the MPIWG library (Fig. 2) to compare the cover of the facsimile of *Manuscript H* held by the IdF (national edition, 1986) with the images available, at least until early 2019, on the website of the *Agence photo de la Réunion des Musées nationaux* (www.photo.rmn.fr). The IdF itself referred to this official website and gave to understand that these were photos of the originals (Fig. 3–4).

Fig. 2. Giunti Editore facsimile of the Manuscript H. Bibliothek of the Library of the Max Planck Institute for the History of Science. Photo: Lukas Külper and Marvin Müller

Fig. 2. Giunti Editore facsimile of the Manuscript H. Bibliothek of the Library of the Max Planck Institute for the History of Science. Photo: Lukas Külper and Marvin Müller

Image:
17_Becchi_Renn_Dialog_02

Fig. 3. Facsimile of the Manuscript H. Institut de France (Paris). Photo: Antonio Becchi from the website of the Agence photographique de la Réunion des Musées nationaux (www.photo.rmn.fr), March 11, 2019

Image:
17_Becchi_Renn_Dialog_03

Full Images not Cropped:
17_Becchi_Renn_Dialog_03_left

17_Becchi_Renn_Dialog_03_right

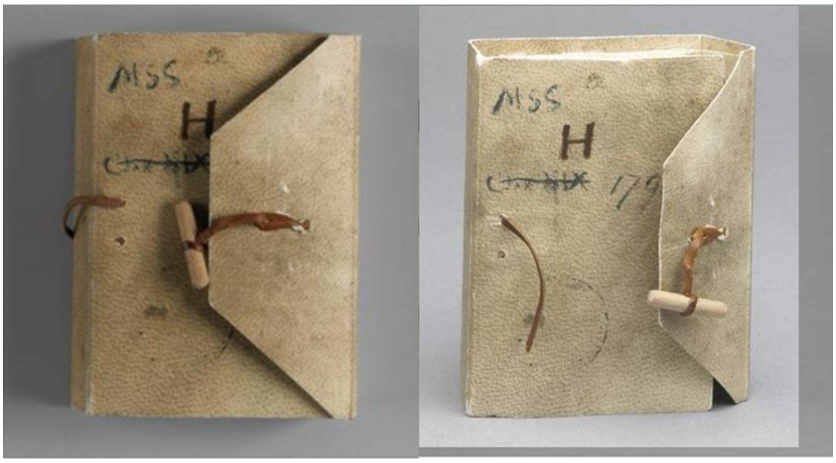

Fig. 3. Facsimile of the Manuscript H. Institut de France (Paris). Photo: Antonio Becchi from the website of the Agence photographique de la Réunion des Musées nationaux (www.photo.rmn.fr), March 11, 2019

However, I was immediately struck by differences between the two bindings of *Manuscript H,* so in January 2020 I decided to travel to Paris to see the major Leonardo exhibition at the Louvre, where all the IdF's manuscripts were on show. To my astonishment, I found that the original binding of *Manuscript H* differed from both the reproductions known to me. I thereupon asked the colleagues at the IdF for an explanation. They told me that those photographs were of their Giunti's facsimile. Later, some weeks after I had seen them online and during the celebrations marking the fifth centenary of Leonardo's death (1519–2019), the *Agence photo de la Réunion des Musées nationaux* replaced the photographs of facsimiles with ones of the original items. Surprises of this kind really do pull the rug from under one's feet.

JR – Your research appears to have opened a Pandora's box and we can only guess at its far-reaching consequences. Evidently, there are still many open questions: not only does the provenance of the *Codices Forster* remain to be clarified but also the role of the National Edition, which is considered an essential work of reference for any study of Leonardo.

AB – Yes, and in my opinion the problem is not individual oversights—mistakes happen, after all—but rather methodological errors, a lack of care and attention to detail. And as we've already said, we should not forget that such errors have a major impact on research to this day.

JR – But perhaps there's another way to look at this: the National Edition stands in a long tradition of print publications, whose entire design and methodology rests on treating manuscripts first and foremost as raw material for the printed word. Owing to the complexity of the manuscript material—given the problems of reproducing images or laying out non-linear texts, etc.—such print editions often go wrong on technical grounds alone. However, we have long since moved beyond the Gutenberg era into a new age, namely that of the digitalization of knowledge, of cultural heritage, and not least of Leonardo's manuscripts. Little wonder, then, that the shortcomings of a classic print edition catch the eye.

AB – You are quite right. High-resolution digital editions that are publicly available online—in the spirit of open access—are of immense value, especially if otherwise the facsimiles alone are accessible, as in the case of the 12 held by the IdF, available for consultation only on extremely rare occasions. The MPIWG's ECHO project (*European Cultural Heritage Online*, https://echo.mpiwg-berlin.mpg.de/home) broke new ground 20 years ago in this respect, setting benchmarks in many fields. And with regard to work specifically on Leonardo, Romano Nanni (1952–2014) and Monica Taddei and their collaborators made a similarly pioneering achievement with their magnificent *e-Leo* project launched in 2007, the new edition of which went online on November 25, 2019. The digital *e-Leo* archive is rooted in that rare generosity and intellectual enterprise characteristic of all of Romano's projects, and of Monica Taddei's work to this day. In my opinion, their project is one of the greatest contributions of the last hundred years to the study of Leonardo's manuscripts, and marks an unparalleled turning point in research.

JR – Does it therefore solve the problems that you've mentioned?

AB – No, it doesn't, because the *e-Leo* project, too, is largely based on Giunti's facsimiles and so is necessarily affected by what we've just been discussing—in particular the matter of the bindings. The difficulties I have encountered in my research, and the issues I've been able to raise, highlight the importance of a new generation of digital projects.

JR – What exactly do you mean by that?

AB – I mean projects that treat manuscripts and other documents as 3D objects and display them at high resolution in a way that renders visible not only the text and drawings on a page but also the watermarks, holes, the peculiarities of color and other traces, as well as physical characteristics such as the thickness of the sheets. The same should apply also for bindings, which are of fundamental importance in reconstructing the "biography" of any Leonardo's manuscript. As my experience with the *Manuscript H* binding shows, there's still a great deal of ground to cover in this field, and a need for far more research.

JR – Peter Damerow (1939–2011) and Robert K. Englund (1952–2020) pursued this course in the framework of the equally pioneering digital humanities venture they founded in 1998, the *Cuneiform Digital Library Initiative* (CDLI: https://cdli.ucla.edu/). But I understand exactly what you mean: basing a digital edition on facsimiles will never suffice, especially not in the case of Leonardo's manuscripts, whose physical characteristics can offer us vital insights into their provenance and context. Insofar, it seems there really is a need for the second digital generation, at least as far as Leonardo is concerned.

However, as you well know, this encyclopedic aspiration to fully exploit the new media's potential drove digital library programs of this sort from the start. I'm thinking, of course, of our electronic representation of Galileo's *Notes on Motion*, online since 1999 as a result of our institute's collaboration with the Museo Galileo and the National Library of Florence (https://www.mpiwg-berlin.mpg.de/Galileo_Prototype/INDEX.HTM). But this idea of comprehensive digitization has struggled to take hold, unfortunately, probably also because of the enduring appeal of the classic print format. Is this the case also with Leonardo?

AB – Well, as I can still vividly recall many conversations on this topic with our late mutual friend Peter Damerow, the shortcomings of the endeavor are very clear to me. Take a look at the reproductions of Leonardo's Codices currently available online, including the latest and most ambitious ones, and you'll have to admit that we are still a long way from realizing a comprehensive digitization of the *Corpus Vincianum*. One source of great hope at the moment is the collaboration between *e-Leo* and *Leonardo//thek@*, the latter a visionary project initiated by our friend Paolo Galluzzi, the director of the Museo Galileo in Florence. Paolo announced this stupendous venture, which will make available digital reproductions also of the photographic plates preserved in the archive of the *Commissione Vinciana,* way back in 2005, and officially presented it during the Leonardo celebrations in 2019. So far, it has focused mainly on the *Codex Atlanticus*.

JR – When working on Galileo's manuscripts on motion—they too, a disorderly corpus of loose folios—we found that watermarks were a great aid to dating individual pages and reconstructing connections between them. Is this the case also with Leonardo's manuscripts, which alone in terms of volume present a far greater challenge?

AB – As far as the watermarks on Leonardo's manuscripts and drawings are concerned, we unfortunately have to admit that not even now—after almost 150 years of in-depth research into most of these documents, more than a century after the foundation of the *Commissione Vinciana*, and 50 years after the launch of the National Edition—is there an online database at our disposal that would facilitate the comprehensive analysis and comparison of individual documents. Close study of the watermarks and bindings was evidently never a priority—to the great detriment of Leonardo scholarship.

JR – And concerning the *Codices Forster* in this respect, our primary inquiry?

AB – After all that has been said, you can probably guess: not even in the 1992 National Edition of the *Codices Forster* were the watermarks reproduced, although they are clearly visible in the originals, and of particular significance.

JR – Then how do you plan to proceed and what challenges do you see ahead for Leonardo research?

AB – In my opinion, research such as I have begun can be successfully pursued only by an international group of experts. I have already discussed this with certain colleagues who have been studying Leonardo and his manuscripts for decades. There are delicate issues at stake here, which, as you've rightly pointed out, may open a Pandora's box. Above all, we need the support of the CNV and the Giunti publishing house, if our work is to continue, especially when it comes to the history of the National Edition. But of course, it also concerns other institutions that hold Leonardo documents. Clarifying the history of the National Edition is fundamental to future proceedings, since that edition has shaped the current state of Leonardo research in so many respects. Just think of the fact I mentioned earlier, that the IdF holds a facsimile of uncertain provenance that apparently was on display on the website of the *Agence photo de la Réunion des Musées nationaux* for over 15 years.

JR – What role could the CNV play in this?

AB – I consider it important, for example, to convince the IdF and the V&A to put the Leonardo manuscripts in their possession on the same table, in order to examine the striking similarities between some of them, to carefully investigate the bindings, to study in detail every single peculiarity of the paper, inks, colors, and watermarks, etc. The CNV could play a crucial role in persuading the two institutions to cooperate in this way and make the manuscripts available to this end. This would not only enormously simplify research into the mysterious origins of the *Codices Forster* but also help clarify other open questions regarding Leonardo's manuscripts, including their chronology and the connections between them.

JR – And how do you see your role in this? Which research issues do you intend to pursue, and might your findings cause even more of a stir?

AB – My lines of research to date do indeed highlight problems and contradictions in other areas of Leonardo scholarship, but are still in their early stages. Whether they will cause a stir, I really cannot say. But they may well show us how important it is to re-read the history of the National Edition, to reconstruct the mysterious origins of the *Codices Forster*, and to reopen some long-ago-archived Leonardo files. My overall impression is that the premature certainties on which some of the research into Leonardo's manuscripts has rested for decades are numerous, widespread, and not easily brought to light. It is this impression that we intend to put to the test in the months and years to come.

JR – By which you mean that the fantastic potential of electronic media, in particular for Leonardo research, will finally be taken seriously and exploited in full?

AB – Yes, but it won't be solely a matter of visionary and pioneering projects, although these undoubtedly exist, but also of new forms of research and new forms of cooperation between the conservators of Leonardo documents, in combination with publishing ventures. And while these may be steps into a new world that has yet to be shaped, this itself holds untold opportunities to apply the rules of good scientific practice—because the new media provide us with a new way to verify established research claims, namely recourse to comprehensive reproductions of original manuscripts.

JR – Are you implying that Leonardo research in the past has not always been rigorous enough when verifying such claims?

AB – Allow me to answer that by citing the great Romanist Carlo Dionisotti (1908–1998):

> While it is true that we can all make mistakes in research, and indeed inevitably do make mistakes, it is equally true that we must be able to rely—without constant, elaborate, and humiliating checks—both on our goodwill and that of others, as well as on all our modesty, elementary prudence, and diligence (se è vero che tutti possiamo, nella ricerca, sbagliare, e di fatto sbagliamo, inevitabilmente, è però anche vero che dobbiamo poter fare assegnamento, senza continui, dispendiosi e umilianti controlli, sulla nostra e altrui buona volontà e modestia, elementare prudenza e diligenza) (C. Dionisotti*, Appunti sul Bembo,* "Italia Medioevale e Umanistica," VIII, 1965, p. 277).

JR – But is this where Leonardo research differs from other areas of historical and philological research? Is Leonardo an exceptional case? Do you think the Leonardo myth and the fascination that his work exerts have clouded certain scholars' outlook? Or has research here perhaps in some cases submitted too humbly to the authority of individual great scholars who have studied Leonardo's written and graphic legacy of over 4,000 pages, in its entirety, without ever initiating further critical inquiry into, say, the origins of his manuscripts?

AB – Yes, on both counts. What we need, in any event, is some critical self-reflection on the part of we scholars ourselves, self-reflection that is not only in the spirit of Leonardo but also in the spirit of Leonardo research, and accordingly strives to stop treating Leonardo as an "exceptional case," to use your term. It seems some researchers have tacitly agreed that the Leonardo myth gives them carte blanche to neglect that diligent attention to sources which in all other fields of research is a *conditio sine qua non*. At least that is what the preliminary results of my research and the problems I have encountered suggest.

JR – It's true that Leonardo fires the imagination, and not only that of the experts—just take Dan Brown's *The Da Vinci Code* (2003), for example, although the novel, as we well know, paints a fantasy world. How much fantasy can we allow for in the Leonardo research field?

AB – In my view, it's high time to debunk as shreds of fantasy some of the privileged historiographical gems that have long been enshrined in the *sanctum sanctorum* of Leonardo research. Dionisotti reminds us of a point made by Giovanni Mercati (1866–1957) and which still applies:

> It was ultimately a question of solidity, of a different degree on the scale. For years we had worked on, and believed in, a glass philology. There was nothing wrong with that: it was legitimate and honest work that could also produce beautiful and precious things. But we had to realize in the end that they were fragile things, that they were

> glass and not diamonds (Era per l'appunto questione di durezza, di un grado diverso nella scala. Per anni avevamo lavorato e creduto in una filologia di vetro. Nulla di male: era una industria legittima e onesta, e poteva anche produrre cose belle e preziose. Ma bisognava rendersi conto che erano cose fragili, che era vetro e non diamante). (*Testimonianze a don Giuseppe De Luca* (III), "Lettere Italiane," 1962, 14(2): 225–226)

Likewise, in the Leonardo research workshop: knowing how to distinguish glass from diamonds always comes in useful.

Translated from the German by Jill Denton

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And you must know, that. … the human being is the model for the world
Leonardo da Vinci
Codex Arundel, 156v

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