A Silent Evolution

Material Engagement and Knowledge behind the rise of Paper Technology across Italy and England (1590-1800)

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Maria Alessandra Chessa, September 2019

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ABSTRACT

The research follows questions arising from a scientific illustration of asbestos, once part of the paper museum of Cassiano dal Pozzo (1646 ca.). As a physical object, capable of perceptually illustrating the filamentous nature of the mineral through a noticeable lint textured sheet, the illustration invites consideration of the scope of the fibre-made medium of paper. What brought paper to be so finely adopted by Cassiano as an expressive tool? What understanding did users have of the substance they used? To what extent did paper contribute to the development of the contents it carried? The aim of the thesis is to present a new, material-focused narrative of paper history in the contexts of Italy and England. In particular, the thesis explores the engagement of the learned and craftsmen with paper as a pervasive substance, in connection with a crucial phase of scientific and technological development between the end of the 16th and the 18th centuries.

The project moves away from the conventional ground of paper history and embraces a broader perspective offered by the theories and methodology of material culture. It derives evidence from and within objects, including adopting an ethnographic approach to study papermakers' understanding of fibres, a topic largely inaccessible through archival sources.

The argument develops across three main instances of material engagement of the scholarly world and workshop practices with paper: using, looking, and making. It aims to

demonstrate how each of these, with different modalities and contexts, mobilized thought, engendering the articulation of knowledge.

The first instance of the material engagement with paper focuses on its instrumental function and delineates a significant transition from the artisanal practice to that of the scientific community. By looking in particular at nature prints and herbaria as epistemic objects, the analysis traces a progression in the adoption of that versatile material technology for visualization, from the development of textual and figurative contents to the physical inclusion of actual specimens. The second instance, on the visual engagement, addresses the rising awareness of paper as a fibrous matter within the new scientific interest for fibres among the learned. From the earliest appearance of paper samples in the cabinets of curiosity to the observations of Bacon and the Linceans, the section reveals how such scrutiny into paper's matter prompted questions regarding the theoretical framework of the artificial/natural dichotomy, stimulating the emerging understanding of organic physiology in early modern Europe. The third aspect investigates the technique of papermaking as an applied process of knowledge production. The material cognition of paper is explored through the different perspectives of naturalists, who accessed paper mills as an empirical means to investigate fibrous substances, and papermakers, depositaries of dynamic and long accrued insights into the fibres' functional properties.

As a whole, the thesis demonstrates that, between the 17th and 18th centuries in Italy and England, engagement with paper did not simply end with the embrace of a technology, although complex. As a heuristic tool, with its substance of meshed fibres, paper became crucially ingrained in the same advancement of knowledge to which it was making a significant contribution as the principal material for books. The thesis thus outlines a vital involvement of the spheres of art and science with the material of paper: one that engendered knowledge in a mutual progression. While the new scientific observation into living matter and the nature of fibres helped driving the artisanal process of papermaking, the latter supported scholars in their journey of discovery. As a result, the consequence of such exchange shaped the development along with the material landscape of European civilization itself.

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Introduction

The present research is a study of paper history that contemplates how the human engagement with that material went on to significantly shape both the European culture and the mindset between the late 16th and the 18th centuries, with a particular focus on England and Italy. This introduction is going to summarise the main elements and questions raised within the thesis, before addressing the core arguments of the research. I will explain here how the study was first conceived, the research questions that emerged from that early insight and the context of the studies from which I primarily drew my reflections. The key ideas of the thesis are also going to be discussed, along with the research methods adopted and a synopsis of the arguments, as developed in the chapters. To explain the concepts that underlie this project, I am going to begin by describing an encounter with an earlier work on paper in the early modern period, which first encouraged my enquiry.

The idea of the project was conceived as an afterthought from the reading of a paper by Ivo Mattozzi, a preeminent historian of Italian paper.[1] "The Silent Revolution", which was the title of the contribution, was the heading of a section of a 1988 catalogue for an Italian

[1] Ivo Mattozzi, "La Rivoluzione Silenziosa" in Giorgio Raimondo Cardona (ed. by), *Charta: Dal Papiro al Computer*, (Milano: Mondadori, 1988), pp. 146-164.

exhibition on writing supports. Although Mattozzi had written widely about the history and trade of Venetian paper, the main argument of that essay was different. It concerned the progressive impact of paper on the rise of the printing press in early modern culture, which had only been possible by virtue of that material support and its overlooked growing availability at that time: an essential aspect to consider for appreciating the Venetian vitality within the printing trade. However, when reading that essay, at the very beginning of my PhD research, its heading on the "the silent revolution" of paper suggested to me something different than what the author was arguing. Based on my studies and observations, as I will clarify shortly, I was expecting to find an argumentation about how paper had been a ground-breaking material on its own, rather than having been merely functional as a support for the printing press. Therefore, after the reading, I was left dissatisfied. The essay, written about 30 years ago, could not answer some of my unsettled questions on the actual role of the material of paper as an extremely versatile medium that fulfilled innumerable applications, inevitably shaping practices and mindsets in turn. Among all the functions the printing press clearly represented only one of the possible applications. Nonetheless, Mattozzi's heading raised my intellectual concerns, eventually prompting my actual research. It was clear to me that paper had had a far wider and implicit influence on our culture than that which Mattozzi's essay described. Indeed, the impact of paper reverberates even today in our practices, in many ways, although those may not appear immediately evident. The simple fact that I write documents on my laptop stubbornly adopting the conventional paper-like layout with dark text on a white background, instead of white lettering on blue, which would allegedly be easier to view, is meaningful in my personal attachment to paper as the material that I have always been familiar with during my life. Our deep involvement with paper is indeed subtle. Therefore, it was reasonable for me to wonder whether and how our long engagement with paper had affected our habits and practices, gradually shaping our culture and, possibly, even our thoughts at a crucial time between the 16th and 18th centuries. As a result of those reflections, I conceived my historical investigation around some research questions: How did paper affect the European culture in the age of transition corresponding with the rise of new knowledge, progress and the growth of prosperity?[2] To what extent did paper play a role in the significant development of technology and science between the late 16th and the 18th centuries? The aim of my actual research, therefore, has been that of presenting a new, material-focused narrative of paper history that may unfold the active impact of such a material. In order to pursue this aim, my investigation

[2] For a definition of that age of transition towards modernity and its time frame see: Joel Mokyr, *A Culture of Growth: The Origins of the Modern Economy*, (Princeton: Princeton University Press, 2016).

thus wants to explore the human engagement with paper as a pervasive and compelling substance, with a specific focus on the way such an involvement determined the practices and knowledge of both scholars and practitioners.

At the time I started to envision my research, it was clear to me that my questions were ingrained in the mindset of my recent studies on the V&A/RCA MA in History of Design, during which I had just explored, in my MA dissertation, how paper had been proficiently and imaginatively embraced in the culture of Renaissance Italy.[3] The engagement with such a material was so profound in that cultural context, that paper was even adopted as an evocative medium for people's votive effigies with the function of epitomizing the human body and taking part in the spiritual dialogue with the divine grace.[4] My expectations, therefore, were influenced by the fresh air of the "material turn" and the material culture's literature that I just had the opportunity to encounter during those studies. As a consequence, the present research is profoundly informed by that academic training in Design History, as well as the literature of material culture and especially the theories of materiality encountered during those studies.

My expectations of Mattozzi's contribution were unreasonable. In 1988, when that essay was written, it was possibly too early to find an answer to my questions on the radical impact of the material of paper in the words of a traditional paper historian. This is possibly because the seminal work "The Social Life of Things" edited by Appadurai, one of the first books that started to draw the attention of scholars to objects and the way they establish an integral and meaningful part of a culture, had been edited only two years earlier than Mattozzi's contribution.[5] Moreover, the theory and methodology of material culture, as espoused by the art historian Jules Prown, were at their dawning.[6] At that same time, but from a completely different viewpoint, cognitive studies were still mostly curbed by the boundary between mind and body, with the former being limited to the brain and the concepts of extended or embodied mind still far from being the familiar expressions they are now. The connection between all of those diverse disciplines might have appeared unconventional and it was possibly even harder to conceive an interdisciplinary link between them, until it started to emerge from the

[3] Maria Alessandra Chessa, *Between the Ordinary and the Extraordinary. Experimentations and practices on paper in Renaissance Italy*, MA dissertation, 2012, Victoria and Albert Museum/Royal College of Art.
[4] Maria Alessandra Chessa, "The Substance of Divine Grace. Ex-votos and the Material of Paper in Early Modern Italy" in Suzanna Ivanič, Mary Laven, Andrew Morrall (eds.) *Religious Materiality in the Early Modern World*, (Amsterdam: Amsterdam University Press, 2019), pp. 51-66.
[5] Arjun Appadurai (ed. by), *The Social Life of Things. Commodities in Cultural Perspective*, (Cambridge: Cambridge University Press, 1986).
[6] Jules D. Prown, "Mind in Matter: An Introduction to Material Culture Theory and Method", *Winterthur Portfolio,* vol. 17, no. 1, 1982, pp. 1-19.

theoretical field of Cognitive Archaeology and Anthropology, as well as on a philosophical basis.[7] Although not directly contemplated in the present work, the direction indicated by those studies pointed me to the widest contextual literature from which I was able to draw valuable insights in order to delineate the sense of my research.

Furthermore, a personal viewpoint represented a favoured circumstance for my investigation. When Mattozzi was writing his essay, the world was rather different from the one we are experiencing now. Our European society was still very much immersed in the same culture of paper as it had been for centuries. In that context, I found myself suspended as an exponent of the last generation who had experienced the absolute pervasiveness of paper, but also of the one that had witnessed the emergence of computers, a time during which paper seemed bound to surrender to the new digital devices. As a student, I had experienced first-hand the transition of library catalogues from a physical space, or a large piece of furniture that stored myriads of cards, each indexing a tangible book on the shelf, to the earliest appearance of online directories. I have also started to appreciate the advantages of downloading e-books and articles in digital format, as well as easily searching for words or references within those documents: a substantial change in front of my eyes. The advantage of my point of view was that I could not be in a better place to try disentangling what paper may have meant in the past, possibly more easily than someone writing in the 1980s. In other words, when I embraced the project for my PhD, I wanted to attempt to understand and be able to illustrate what I wished to read, but could not find, under that heading on the actual "silent revolution" of paper in the critical age of European development between the late 16th and the 18th centuries. Besides this, I chose to explore Italy and England within the European milieu as two representative countries at that time for the history of paper as a material. Within such a context I conceived my project as the exploration of an implicit transition or, as I wanted to name it: "a silent evolution".

Key ideas explored in the research

What Mattozzi's heading was evoking to me is now clear. The expression "silent revolution" could not have been more appropriate to define what my research concerning paper wants to address. Nonetheless, following Edgerton's reflection, the ground-breaking role of that material

[7] Carl Knappett, *Thinking through Material Culture,* (Philadelphia, University of Pennsylvania Press: 2005). Merlin Donald, *Origins of the Modern Mind* (Cambridge MA: Harvard University Press, 1991). Colin Renfrew, "Towards a Cognitive Archaeology" in Colin Renfrew and Ezra Zubrow, *The Ancient Mind: Elements of Cognitive Archaeology*, (Cambridge: Cambridge University Press, 1994), pp. 3-12. Beth Preston, *A Philosophy of Material Culture*, (New York, London: Routledge, 2013).

had to be acknowledged as a process in which the impact of paper is distributed in our history, and not only with regard to its first appearance in Europe.[8] Rather than being simply expressed, the concept of "silent evolution" needed to be clarified with facts and evidence in the historical context I was considering. The major role of paper therefore needed to be explored by delving into its material discernment without eluding the widest historical overview of the episodes investigated. However, tracing the circumstances of that phenomenon presented a major challenge, precisely because of the silent character of paper's engagement. The attribute "silent", with regard to paper's ascent, was already dense with connotations during the Renaissance. It has long been clear to paper historians that, in conjunction with the diffusion of the printing press, the demand for paper was boosted.[9] In turn, its production increased, and it could not have been otherwise. The printing press was unquestionably a revolutionary technology in early modern Europe and its extensive impact is not to be underestimated. However, although paper was a paramount contingency for the growth and progression of such a technology to take place, the attention upon that material and the fact that its production escalated often remained negligible in the literature. Paper is frequently reduced to silence, as if an incorporeal content which was a separable entity from its tangible support and, consequently, it could be observed in isolation: an utter incongruity which a branch of British literature studies has started to debate since the 1990s.[10] Since we are inclined to consider technologies in the same way as innovations, taking place as precise events in time rather than multifaceted and complex processes, paper's long-term impact and the significant changes in its perception has been mostly taken for granted.[11] This may have happened not just because paper has been seen in a close continuity of function with parchment, despite those two writing supports being substantially different, but also because paper has been used in Europe since the Middle Ages. Paper, therefore, did not represent a radical novelty in comparison with how the printing press was rather seen and experienced in early modern Europe. The fact is that paper, as my research wants to demonstrate, should be considered as a tool that went on to be

[8] David Edgerton, *The Shock of the Old: Technology and Global History since 1900*, (London: Profile, 2006).

[9] The significant spread in the use and manufacture of paper in relation with Gutenberg's invention has always been clear. Donald C. Coleman, *The British Paper Industry, 1495–1860: A Study in Industrial Growth*. (Oxford: Clarendon Press, 1958), pp. 7-8. A large examination of paper samples produced in Italy during the 15th century has now proved how, in conjunction with the diffusion of the printing press, the manufacture of paper changed in order to increase production, thus meeting the sudden rising demand for that good. Ezio Ornato, Carlo Federici, et al. *La Carta Occidentale nel Tardo Medioevo,* (Roma: Istituto centrale per la patologia del libro, 2001).

[10] Only to a certain extent has the interest for the materiality of paper and what it meant to readers and writers started to emerge, raised in the 1990s by a group of English Literature historians, such as Peter Stallybrass and Margreta de Grazia, continuing as a discipline of the materiality of text with the research of others such as Helen Smith, "'A Unique Instance of Art': The Proliferating Surfaces of Early Modern Paper", *Journal of the Northern Renaissance*, vol. 8, 2017. pp.1-39.

[11] David Edgerton, "From Innovation to Use: Ten Eclectic Theses on the Historiography of Technology", *History and Technology,* vol. 16, 1999, pp. 111-136.

gradually and quietly embraced as an extremely influential technology: a ground-breaking one, yet elusive to trace especially from the written primary sources.

There is another significant reason for the "silence" that sometimes surrounds paper. This is due to a major bias coming from the fact that our culture has long relied on a substantial and extensive use of paper, which continues today. Consequently, we could hardly consider in full how its sudden increase in circulation, as boosted by the introduction of the printing press, could have deeply impacted early modern Europe. As the philosopher Andy Clark would say, paper has ultimately become to us a "transparent equipment".[12] We have been dealing with paper for centuries as an essential and pervasive medium that has become part of what we are, in about the same way as a blind man comes to embrace his stick as a part of his own body, as exemplified in a well-known passage sketched by Merleau-Ponty.[13] Such a prosthetic integration with an implement, in order to be observed for what it is, requires a substantial degree of awareness. This is possibly the reason why we may have found it difficult to consider our deeply ingrained involvement with paper so far. More importantly, the use of such a tool, being not pre-determined, has been acquired through common practices thanks to the plasticity of the human mind. The protracted and widespread use of a specific item of equipment had to determine certain consequences in the cognitive sphere of its users, which brought us to adapt to it. Paper was possibly not too difficult to integrate at certain levels: some applications easily replaced the functions of other materials, such as wrapping, before being commonly identified with textiles, or writing associated to parchment. Other applications and experimental uses were clearly far more refined and distinctive to paper, which is what I want to explore in more detail.

A clear example of an advanced use of paper was already well known to me and came from some of the Leonardo da Vinci drawings that I had studied. As I was able to observe during my MA research, Leonardo imaginatively combined drawing with the versatile physicality of paper sheets in a way that would not have been possible with any other support.[14] Paper's two-dimensionality and transparency, along with its ability to be folded and pricked, enabled Leonardo to manipulate the graphic sign that he sketched onto such a versatile support as if it were conceived on a virtual dimension.[15] The process apparently allowed him not only to simply

[12] Andy Clark, *Natural Born Cyborgs. Why Minds and Technologies are made to Merge,* (New York: Oxford University Press, 2003).
[13] Maurice Merleau-Ponty, *Phenomenology of Perception*, (London: Routledge, 1962), p. 166.
[14] Maria Alessandra Chessa, *Between the Ordinary and the Extraordinary. Experimentations and practices on paper in Renaissance Italy*, MA dissertation, 2012, Royal College of Art/Victoria and Albert Museum, p. 38, figs. 26, 27.
[15] Leonardo widely explored the material manipulation of paper, not only in the well-known depiction of the cardiovascular system of a female body, but also in other representations, such as a preparatory study of a male physiognomy in the Royal Collection at Windsor.

draw subjects of anatomy and physiognomy, but also to think and contemplate on the objects of his studies through their materialization on paper. Such cases were crucial for my later reflection on the material of paper and led me to consider how thought profitably combined with the physical medium: a way in which paper was not just a mere support to the cognitive process, but an active constituent of it. If Leonardo, as it seems, was empowered to think by means of the medium of paper and through its manipulation, we should describe his act as "embracing" that material, rather than merely "using" it as a passive support. So, it was clear to me that my study of paper had to start from the practices involving the material. From the literature of the history of paper, we know that paper has been produced and sold primarily for writing, printing and wrapping since the Middle Ages. Although, by the 18th century, the varieties of paper had rapidly increased, all of those marketed functions have little significance when defining the actual engagement of people with it. My research, therefore, brought me far from the established debate of paper historians, as I wanted to better explore what such an engagement with paper involved in that crucial time for European development.

Some theories related to the material culture, and the studies of materials in particular, have been especially important in formulating my argument. To some extent, the concepts of "agency" formulated by Alfred Gell responded to my necessity to investigate the role of paper within European culture and its development, especially as he indicated an active role of the material sphere within the human experience. On the other hand, the "theory of affordances" by Gibson explored how the material world expresses its nature through its perceived potentialities for action.[16] Nevertheless, despite being both relevant and valuable, such theories did not clarify the complex dynamics within the interaction between man and his environment. Therefore, I found a more comprehensive framework for my analysis in the "actor-network theory" by Bruno Latour, which delineates a model of distributed agency between the human sphere and the material one.[17] Among the philosopher's writings, the essay "Visualization and Cognition: Drawing Things Together" has been especially relevant. [18] The analysis of the specificity of modern scientific culture in Europe, as it emerged in that essay, hinted at a key function of paper in many ways, which I have actually encountered during my own research. Several other studies, moving directly from Latour's theorization, have also been determinant.

[16] Alfred Gell, *Art and Agency: An Anthropological Theory*, (Oxford University Press, 1998). James J. Gibson "The Theory of Affordances" in Robert Shaw, John Bransford (eds.) *Perceiving, Acting, and Knowing: Toward an Ecological Psychology* (London: Routledge, 1977), pp. 67-82.

[17] Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005).

[18] Bruno Latour, "Visualization and Cognition: Drawing Things Together" in Henrika Kuklick, Elizabeth Long, *Knowledge and Society. Studies in the Sociology of Culture Past and Present*, vol. 6, (Greenwich: Jai Press, 1986), pp. 1-40.

One is the "entanglement theory" by Ian Hodder, which helped me to discern with clarity a distinctive dynamics of symbiosis concerning paper: the human reliance on paper versus the dependency of paper manufacture on the human consumption of linen textiles. Another influential study is the "material engagement theory" by Lambros Malafouris, which invited me to reframe the human involvement with paper in a cognitive key.[19] As I approached my exploration and study of paper, I also kept in mind the theoretical indications that emerged from Ann-Sophie Lehmann's study of the artistic medium of oil, which extrapolates from those previous theories.[20] The result of those background was that I approached the emerging field of new materialist studies, attempting to provide a possible novel line of enquiry based on the material engagement theory.[21] On that assorted theoretical ground, I aspired to answer my general questions by delving into a historical survey of how the material medium of paper shaped European culture.

Research methods and archives

On such premises, in order to address my questions, the research inevitably starts from the traditional historiography of paper history. Nonetheless it necessarily moves away from the perspective and approach that conventionally concerns that kind of historical investigation. The adoption of theories and methodologies of material culture eased that shift, as my study draws its evidence from a combination of written and material sources, with particular attention over the importance of objects and practices. In the overwhelming assortment of paper artefacts from the timeframe of my analysis, I especially focus on some that appeared more significant with regard to my questions. Those objects, therefore, rather than illustrating my research, take the centre stage and lead my argument. As an example, while Matthias Koops' book printed on straw paper opens the first chapter and poses preliminary questions, indicating a direction, the drawing depicting asbestos from the Paper Museum of Cassiano dal Pozzo determines and follows the structure of my whole argument. In order to study specific objects, therefore, my

[19] Ian Hodder and Gavin Lucas, "The symmetries and asymmetries of human-thing relation. A dialogue", *Archaeological Dialogues*, v.24, n.2, 2017, pp. 119-154. Ian Hodder, "The Entanglement of Humans and Things: A Long-Term View", *New Literary History*, 45, 2014, pp. 19-36. Ian Hodder, "Human-thing Entanglement: Towards an Integrated Archeological Perspective", *Journal of the Royal Anthropological Institute*, n.17, 2011, pp. 154-177. Lambros Malafouris, *How Things shape the mind. A Theory of Material Engagement,* (Cambridge, MA: MIT Press, 2013).

[20] Ann-Sophie Lehmann, "The matter of the medium: some tools for an art-theoretical interpretation of materials" in Christy Anderson, Anne Dunlop, Pamela H. Smith (eds.) *The Matter of Art: Materials, practices, cultural logics c.1250-1750*, (Manchester: Manchester University Press, 2015), pp. 21-41.

[21] On the emerging of New Materialisms see: Iris van der Tuin, "On the Threshold of New Materialist Studies" *Forum*: *University of Edinburgh Post-Graduate Journal of Culture and the Arts*, n. 19, Autumn 2014, pp.1-12.

analysis considers different perspectives of investigation, covering direct observation and references from primary written sources, along with the relevant, more recent literature. In a specific case, the study of an 18th century example of blotting paper, the investigation rather turns to an ethnographic approach. On that occasion, since my reflection on the artefact posed questions that I was not able to answer, and for which I could not find any adequate primary written sources or literature, I discussed them with both a senior conservator of paper and a papermaker expert in historical techniques and raw materials. The precious insights attained through the ethnographic means allowed me to deepen the comprehension of that specific sample of blotting paper and ultimately allowed me to place such an artefact in a significant, unforeseen context concerning the artisanal and scientific exchange/transition of knowledge.

Whereas objects present an important aspect of my argument, many of my questions also originate from the analysis of primary written sources. In Italy, an important archive that I visited is the Archivio dell'Accademia Nazionale dei Lincei in Rome, which preserves the invaluable correspondence of Cassiano dal Pozzo. Nonetheless, except from that single case, I occasionally found archival records to be more relevant for their physical evidence as material supports, rather than for the contents those documents were carrying. My research in Genoa's archives, during the preliminary stage of my project, led me to consult a number of documents from both the Archivio di Stato and the Archivio Storico del Comune. The type of documentation in those archives, primarily notarial in the former and administrative in the latter, resulted in them being of little relevance to my questions. Nonetheless, the overwhelming quantity of paper sheets still held in the port city's archives, despite the many lost through time, was determinant to my realization of how much of the life in Genoa was registered and actively regulated through the medium of paper directly sourced from the local manufacture. That permeating trait of Genoa's paper culture became especially clear once I started to explore the archives in London, which led me to recognise the difference in the documentation present in there with respect to what I came across in Italy. In England, my research focused on the National Archives and the London Metropolitan Archive and I was immediately struck by the limited number of documents compared to the Italian archives. Nonetheless, the English archives were not less precious for the heterogeneity of such written documentation and the occasional presence of unconventional paper artefacts that conservators had preserved with invaluable carefulness. This is how it has been possible for me to trace several extremely interesting samples of low-quality brown paper used as wrappers, which are going to be discussed in the thesis. Although the content of archival documents has been of limited relevance to my research, printed editions such as scientific and philosophical treatises, along with literary works, emerged as

meaningful sources. Those have been especially important to address the subject of the increasing knowledge of fibres as an organic matter in the 17th century scientific field. Through a number of contemporary scientific and philosophical publications, I was able to trace how this knowledge of fibres, which is an emerging subject in the current literature of science historians, was also encouraged by the direct observation of paper.

Thesis structure and argument

The argument of my thesis is developed in four chapters. The first of these is an introductory part that draws an essential account of paper's history from the main literature. Such a historical progression is presented with a specific focus on England and Italy, in particular Genoa. These should be considered as representative cases within the European context for studying how paper affect the context in which it is not just used but also produced, as it going to be better discussed in the first chapter. Moreover, the research primarily considers a timeframe between the late 16th and the 18th centuries as a significant time to reflect on how paper impacted the rise and early development of modern science. The first target of that chapter is to provide the state of the field on which I have developed my research. Moreover, it defines the relevance of the geographic context and the date range that I have focused upon, in order to sustain my further analysis. In addition, it also highlights some aspects emerging from that traditional narrative of paper's history that the studies failed to address, because of their intrinsic limitations in scope. In particular, those elements are the influential use of paper as a medium of accountancy in the rationalization of its manufacture in Genoa and the actual impact of the scientific investigation of fibres: this last aspect being behind the shifting concept of paper that led to it being considered as an innovative material to be explored in all its potentials. On such premises, I suggest extending the historical account to include a different perspective that contemplates paper not only as a mere good to be manufactured and traded, but also as a pervasive substance that was actively affecting developments in Europe. Indeed, the impact of paper on European culture and society had the human engagement with such a material at its core, which ultimately led to the attempts at redesigning paper from new raw materials on an industrial scale.

The core argument of this thesis develops over Chapters II, III and IV. These follow the preliminary considerations and questions expressed in the first chapter, as I acknowledged the material engagement of scholars and practitioners with paper to be a most significant missing aspect within the conventional narrative of the history of paper. In order to explore such an

important aspect, I singled out three instances of the material engagement with paper that emerge as the most relevant ones to my analysis: using, looking at, and making. Before outlining those key chapters, I should explain the choice of these aspects as the most representative ones of the engagement with paper. These instances are not arbitrary but result from my reflection on a scientific illustration of asbestos and the research that followed. That drawing, once part of Cassiano dal Pozzo's extraordinary collection of pictures of natural history known as the Paper Museum, curiously depicts the fibrous stone of asbestos on a noticeably lint-textured sheet of blue paper (fig. 1). My attention was especially focused on that drawing when I learned that its subject was, indeed, a visual study of the diverse applications of asbestos' arcane fibrous matter. As such, Cassiano's choice of the particular paper used as a support presented a remarkable consistency between the pictorial message and the perceptive medium used to convey it. My interest grew even further after my research established that the drawing also pictured the very first example of paper ever made from the fibres of asbestos. The drawing clearly indicated that using paper, looking at its matter, and making it were the best viewpoints from which to explore my own alternative narration of that material's history. That is the reason why the central analysis of the thesis develops in those three core chapters, each of them respectively addressing one of those critical instances of the engagement with paper: using, looking at and making.

Chapter II explores "using paper". After considering the general resourcefulness and the intrinsic versatility of the material, the chapter addresses the instrumental use of paper among the learned. The analysis develops from a growing body of literature that is currently revealing how the support of paper, which was resourcefully manipulated by early modern scientists and naturalists, played an active role in the formulation of textual contents. Following that direction, in order to explore the functional contribution of the material of paper in the formulation of visual content, I consider the particular case of herbaria and nature prints, which emerged in Italy in the 15th century and later spread across Europe. Those techniques, derived from the apothecarial practices and gradually adopted by the international scientific community of botanists, indeed contributed to establishing the authority of paper as a medium of visualization and a proper technology for modern science.

Chapter III, on "looking at paper", addresses the visual engagement with paper and focuses on how the simple act of observing the material determined a new awareness of paper as a substance. From the inclusion of paper among the *artificialia* in the cabinets of curiosity to the first observations by Francis Bacon and the first Linceans, the analysis considers the change to a new perception of paper as an entanglement of vegetal fibres, which overturned the

previously accepted idea of it as an artificial product made from the corrupted matter of rags. That insight on paper's fibrous matter is finally explored through the observations of some naturalists and philosophers, from which paper emerges as an epistemic material that encouraged not only the scrutiny of organic matter's structures but also inspired the exploration of the functionality of fibres within the processes of human physiology.

Chapter IV, which focuses on "making", considers the making of paper as a process that both entails and engenders a most direct knowledge of the material obtained from fibres. My reflection on such a key instance of the engagement with paper moves from the premise that the earliest attempts of making paper from alternative raw materials could not be considered simply in relation to an alleged shortage of rags, as paper historians have generally indicated. Those experimentations rather pertained to the early empirical investigation of fibrous materials engaged in by naturalists. As such, they represent a crucial moment of exchange of knowledge between scientists and craftsmen. The chapter thus develops in two parts. The first concerns the making of paper as an early hands-on practice of investigation of fibrous matter among the scientists and the second one considers how the exploration of fibres also fundamentally pertained to the artisanal making. The first part in particular considers in detail the case of the discovery of asbestos paper as a process of knowledge and how naturalists and botanists engaged with making paper with that same epistemic purpose. The second one investigates the complex practical knowledge of fibres that laid under the idea of the blotting paper. The case of blotting paper, analysed in conclusion of the chapter, testifies to an effective example of the engenderment of knowledge from the artisanal sphere to that of scientists.

Chapter I

The History of Paper:

An account of Italy and England (1590 – 1800)

Introduction

The purpose of the present chapter is to describe the state of the field of paper history on which I have grounded my research. In addition, it also aims at suggesting how that narrative can be developed further from a different perspective. Within the direction of my thesis, therefore, this chapter mainly presents a contextual account emerging from the current studies. It will be useful to note, as a premise, that the traditional literature of paper history primarily see paper as a simple commodity and delineates an account of the developments in the manufacture and its relative trade. By diverging from that literature, my intention is to trace a historical account that also considers paper under the different aspects that determined its development as a material able to be redesigned. The theme of this chapter will be addressed by considering primarily England and Italy, with a particular focus on Genoa, as two representative cases within the European development of paper's manufacture between the late 16th and 18th centuries. After reporting the particular circumstances that characterised the production of paper in Genoa, the chapter broadens the viewpoint over the European context, by focusing on the late and successful development registered in the English case. The respective significant advancement achieved in those two countries is explored, in particular, in the light of the innovation reached in the 19th century with the ground-breaking introduction of cellulose from wood sourced fibres. Although the process of papermaking in the early modern period did not present any major change from the technology developed in the Middle Ages, considering the two diverse geographical contexts in which the craft was embraced, allows us to reflect on how such a significant development evolved. As a consequence, this chapter will explore some crucial convergences in those two areas: from commercial exchanges to the development of the manufacturing technology. It will especially consider the gradual absorption of the craft into a capitalist model of production, subsequent to the increasing competitiveness

in the European market, along with the late progression of that manufacture to an industrial scale. While considering the conventional narrative, I will especially focus on the historical conditions leading to the rise of the artisanal know-how of fibres: a crucial aspect that will allow us to understand the broad influence of paper as a material, which generally remains overlooked by the literature.

The outline of this introductory chapter can be summarised here. The opening section presents the case of Matthias Koop along with his book edited in 1800 and printed on a most peculiar straw paper. The case marks a tipping point in the English manufacture of paper and constitutes the last significant achievement in our time frame, which introduces us to the question of how the history of paper had unfolded until then. The second section presents some contextual aspects in two paragraphs. The first provides an essential description of the technical process of papermaking as improved in Italy in the Middle Ages and practised in Europe until the 18th century. The second one discusses the relevance of the English case within the European context, with regard to the early contribution of the Genoese art of papermaking, made possible by the active exchanges between those two cultures. From those premises, the chapter offers a more detailed account of the respective progressions in Genoa and England in the following two sections. The third section presents, in two paragraphs, the Italian case through the preeminent model of Genoa's manufacture of paper. The first one addresses the conditions that allowed the establishment, since the late 16th century, of a standardised model of production determined by the investments of a group of merchant entrepreneurs. The second paragraph analyses the reason for the slowdown of that rationalised manufacture based on capital and the subsequent conclusion of that phase in the 18th century. In the fourth section, the English case develops in four paragraphs. These will trace the difficulties in the late introduction of the craft in the country, the distinctive traits of the English art of paper, and the achievement of white paper production before the 18th century establishment of papermaking on an industrial scale. The fifth section reconsiders in more detail the case of Matthias Koops. The first of the two paragraphs of this last section addresses the historical figure of Koops, along with his ambitious enterprise and the allegedly rag-free paper he produced. The second paragraph, in conclusion of the chapter, focuses on the broad-minded vision of Koops by considering the determining factors expressed in the content of his book. That vision highlights the difficulty of understanding the episode of Koops from the conventional viewpoint offered by the historiography on paper, leading to the inclusion in paper's historical account of the aspects concerning the European material engagement with paper. Such elements are going to be explored through the following chapters.

1. 1800: Matthias Koops and a paper "from straw"

In September 1800, Matthias Koops (died 1805) was proudly signing a copy of his own volume at the footer of a solemn dedication to George III. The "*Historical Account of the Substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper*" was hot off the press and ready for its readers.[22] (fig. 1.1a) The book wanted to be not simply a cultured reading on paper history, as its title suggests, but rather a ground-breaking book for the English paper industry. A subtitle indeed sombrely stated on its front page: "*Printed on the first useful paper manufactured soley [sic] from straw*". At first sight the look of its paper doesn't disappoint. The sheets appearance is of a most unusual tone and consistency. They present a deep mustard yellow tint with an uneven texture, which invites readers to touch its surface and feel the density of the pages, appreciating their thick body between the fingers while grasping the grain of what inevitably evokes a vigorous pounding of dried and harsh fibres of straw (fig. 1.1b). While the paper may appear coarse and singularly dark, the layout of the book looks extremely formal. A large page format with generous margins frames the text (fig. 1.1c). Each section leaves empty lines and the script is easy to read in such well-spaced pages. Endsheets have been decorated with beautiful red and blue marble paper and the ex-libris reports the name and coat of arms of its owner: The Right Honourable Thomas Grenville (1755-1846). Grenville was a Member of Parliament at that time and, above all, a bibliophile and eager collector of books. He indeed held that volume in great regard and wanted to rebind it in order to match his personal collection.[23] Grenville's volume is one of a small number of copies of the first edition printed on that unusual paper, all meant to reach the libraries of personalities of the time, one of them having being presented to King George III, remarking on the ambition of Koop's venture.[24]

As we are going to see, the atypical straw paper on which the book is printed was anything than a fortuitous outcome, but it was rather the consequence of a complex juncture concerning the history of the material of paper. In that wide-ranging context, Matthias Koops emerged as a resolute entrepreneur immersed in the contemporary scientific approach and conscious of

[22] That copy, signed and dated by Matthias Koops for Thomas Grenville is housed in the Kings Library Tower at the British Library, General reference Collection G.686.
[23] Barry Taylor, "Thomas Grenville (1755–1846) and his Books", in Giles Mandelbrote and Barry Taylor (eds.), *Libraries within the Library (2009). The Origins of the British Library's Printed Collections.* (London: The British Library, 2009), pp. 321–40.
[24] *The Sun*, no. 2536 Thursday 6 November 1800. Reported in: Keri Davies, "William Blake and the straw paper manufactory at Millbank", in Karen Mulhallen (ed. by), *Blake in Our Time: Essays in Honour of G.E. Bentley Jr*, (Toronto: University of Toronto Press, 2010), p. 235-261, fig.10.2.

the benefits of assimilating the observation of nature in order to devise, from that, practical applications and innovation. Koops, therefore, incarnated the enthusiasm and impulses of his time, along with the challenges of a period in which scientific and artisanal knowledge were reaching a critical point of contact. As Mokyr would recognise, the English entrepreneur was fully immersed in the "industrial enlightenment".[25] From the perspective of the present study, his figure represents a chronological boundary. With his attempt to redesign the material of paper between the end of the 18th and the earliest years of the 19th century, Koops marks a turning point that invites us to look back to the early modern time in order to explore from where the modernity of his figure had originated and especially how his peculiar idea of paper was conceived.

2. The context

2.1 The European craft of papermaking

The manufacture of paper, as practised all over Europe in the early modern period, cannot be considered as a completely native craft. As it is well known, the technique originated from a process first developed by the Chinese. In the 8th century, Arabs learned the technique which, through them, reached Muslim Spain in the 11th century, just before paper started to appear in Italy initially as a commodity.[26] During the 13th century, the manufacturing process was significantly improved in Italy and, in line with the politically fragmented condition of the peninsula, it spread across a number of productive areas.[27] Among them Genoa was one of the first centres to develop it. It is in that port city that the very first European document on the trade of papermaking has been found. This is a contract, dated 1235, in which a local papermaker employed for one year the labourer *Gualterius Englesius,* clearly English born, under the strict condition of not teaching or showing to anyone the *misterium,* as the know-

[25] Joel Mokyr, *The Gifts of Athena: Historical Origins of the Knowledge Economy*, (Princeton: Princeton University Press, 2002) pp. 34-35.
[26] Helen Loveday, *Islamic paper. A study of the Ancient Craft.* (London: The Don Baker Memorial Fund, 2001), pp. 19-20.
[27] On the Italian refinement of the papermaking process from that practised in Spain which originated in turn from the technique carried out by the Arabs, see: Richard L. Hills, "Early Italian Papermaking: A Crucial Technical Revolution." In Simonetta Cavaciocchi (ed. by), *Produzione e Commercio Della Carta e Del Libro Secc. XIII–XVIII* (Firenze: Le Monnier, 1992), pp. 73-97.

how of the art was called.[28] The contract has rightly been considered significant for representing a core condition of the art since its earliest foundation for two aspects that it infers. The first is that the craft of papermaking implied a specific knowledge, which the term "mystery" beautifully evokes, and secondly that, due to the complexity of the production process, masters could not work in isolation, but always had to rely on a number of labourers.[29]

The technical process of papermaking, indeed, always entailed structured and dynamic teamwork. The crucial operations were carried out cooperatively by several workers within mills. The raw material of paper consisted primarily of linen rags for making white paper, destined for writing and printing purposes, or a combination of other fibre-based materials such as coarse hemp from ropes and even woollen rags for low quality brown papers. After the raw material was accurately sorted according to their respective qualities, shaken off from the dust, and cut, it was wetted and allowed to ferment. Once ready, the damp material underwent the action of different water-powered stampers, which reduced it to an even pulp through gradual stages of pounding. The master, or an experienced man in charge, supervised that process and decided when the procedure of forming sheets had to start. At that point, the pulp was mixed with water inside a vat to form a milky slurry, into which the "vatman" plunged a wire sieve of the required size, called a "mould". By holding the mould horizontally, the vatman pulled it firmly out of the vat and gave it a series of shakes. The surplus water thus fell away, whilst a thin coat of interlocking fibres were deposited on the mould's surface. The mould was then handed to the "coucher", who turned it upside down on a wooden ledge. After returning the mould to the vatman, the coucher covered the fresh sheet with a felt to form a pile. Once a certain number of sheets were alternated with felts, that "post" was laid under a screw-press to squeeze out as much water as possible. The work was completed by the "layer", who skilfully separated the sheets from the felts and hung them in a ventilated loft, typically located in the upper floor of the mill. Once dried, sheets destined to bear ink were coated, or "sized", with a hot animal-based gelatine to moderate their natural absorbency and hung back to dry again. The last operations concerned smoothing sheets, sorting the flawed ones, and packaging them in quires, rimes, bundles and bales, according to a mostly consistent international standard of respectively 25, 500, 1000 and 5000 sheets.[30] The only significant variation to the process herein

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[28] For the full transcription of the contract see: Charles-Moïse Briquet, *Papiers et filigranes des archives de Gênes 1154 à 1700*, (Geneve: H.Georg, 1888), pp. 35-36.

[29] Renzo Sabbatini, *La manifattura della carta in eta' moderna: Il caso toscano*, PhD thesis, 1988, European University Institute, Firenze, pp. 16-17. For the salaried work on those dates see: Franco Franceschi, "Il mondo della produzione urbana: artigiani, salariati, corporazioni", in Franco Franceschi (ed. by), *Il mondo della produzione: artigiani, salariati, Corporazioni, Storia del lavoro in Italia, Il Medioevo. Dalla dalla dipendenza personale al lavoro contrattato.* (Firenze: Castelvecchi, 2017) pp. 374-420, pp. 400-405.

[30] Dard Hunter, *Papermaking: The History and Technique of an Ancient Craft*, (New York: Alfred Knopf, 1943) ed. 1978, pp. 170-179.

described was the introduction of a piece of machinery called a Hollander, developed by Dutch papermakers in the late 17th century to adapt the processing of raw materials to the windmill technology.[31] The engine consisted of a heavy roll fitted with metal bars which, rotating in a large tub, grinded rags instead of pounding them: a system that eventually superseded the technology of stampers. Apart from the Hollander, whose adoption found inconsistent reception in the different European countries, the process of papermaking in the early modern context did not present any other substantial changes from the one developed in the late Middle Ages.

2.2 England and Italy within the European history of paper

As paper historians know, the English manufacture of paper was a late one to settle in Europe.[32] Nonetheless, over the span of two centuries, the 17th and 18th centuries, papermaking registered a rapid advancement in that country. Its manufacture progressively resulted in a substantial production of white paper which, along with the traditional one of "browns", finally managed to satisfy the internal demand. English papermaking thus reached a significant position within Europe that endorsed an opening toward innovation, unfolding in the 19th century, to which Koops' case clearly related. The core of past literature that explored such a remarkable development in England mostly focused the research on domestic factors.[33] Today it appears clear that the national narrative, without the perspective of the European context, hinders a full comprehension of that expansion. As we are going to see, indeed, more recent studies on the English case, which provide a wider perspective, have started to highlight how the international context contributed to the extraordinary growth of papermaking in that country.

A 2002 study by Maxine Berg emphasises that a long-underestimated foundation for the 18th century innovation in England had to be recognised in the large importing, and circulation, of foreign goods, which brought with it a diffused phenomenon of imitation.[34] That study was a generic one, yet significant. With regard to paper, we know that the English market in the 18th century was not new to imports, since the country had been supplied for centuries with a wide

[31] Richard L. Hills, *Power from Wind: A History of Windmill Technology*, (Cambridge: Cambridge University Press, 1994) pp. 182-191.
[32] Renzo Sabbatini, "Cartai e Cartiere", in Philippe Braunstein and Luca Molà' (eds.) *Il Rinascimento Italiano e L'Europa, Vol. III Produzione e tecniche*, (Treviso: Cassamarca, 2005), pp. 387-403, pp. 390-391.
[33] Donald Coleman, *The British Paper Industry 1495-1860: A Study in Industrial Growth*, (Oxford: Clarendon Press, 1958).
[34] Maxine Berg, "From Imitation to Invention: creating commodities in eighteenth-century Britain", *Economic History Review*, vol. 55, no.1, 2002, pp. 1-30.

range of qualities, coming primarily from France and Genoa.[35] Having long been seen as an economic burden, the importing of foreign paper indubitably generated an impulse. An example of that attitude is well summarised in a quote from *The London Tradesman* (1747):

> "*We are but lately come into the Method of making tolerable Paper; we were formerly supplied with that Commodity from France, Holland and Genoa, and still are obliged to these Countries for our best Papers (...) The French excel us in Writing-Paper, and the Genoese in Printer-Paper, from whom we take annually a great many thousand Pounds worth of the Commodity: However, our Consumption of this foreign Manufacture is lessening every Year (…), and that we are now able to supply ourselves with large Quantities of our own Manufacture, little inferior to theirs, either in Colour and Substance*".[36]

From these words it appears clear that the amount of imported paper established a target to accomplish and a standard to match and eventually overcome. Besides that general circumstance, the literature has recently acknowledged the transnational character of the English development of papermaking, as it derived from the exchange with foreign manufacturers.[37] This aspect emerged while reconsidering both the many interactions with overseas craftsmen and the introduction of key technologies from the continental context, all contributing to a conjuncture with certain favourable internal conditions. It is in the light of such a character of the English progression that we cannot limit our analysis to that country's narrow horizon, but rather need to explore paper and its history from a wider perspective.

Within the continental context, the Italian case is especially significant as it represents a completely opposite position to the English one, and not just in geographical terms. Italy played a leading role in both the development of the papermaking technique and the first appreciation of paper as a good. Since the Middle Ages, indeed, Italian papermakers had established some key technical innovations, among them especially the animal-based gelatine sizing and the system of water powered stampers, which determined the viability of paper as the successful

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[35] John Bidwell, "French Paper in English Books", in John Barnard, D. McKenzie (eds.) *The Cambridge History of the Book in Britain*, vol. 4, (Cambridge: Cambridge University Press, 2004) pp. 583-601. Mark Bland, "Italian Paper in Early Seventeenth Century England" in Rosella Graziaplena, Mark Livesey (eds.), *Paper as a Medium of Cultural Heritage,* (Roma: Istituto Centrale per la patologia del libro, 2004) pp. 243-255.

[36] The quote is reported in full in: Richard L. Hills, *Papermaking in Britain 1488-1988: A Short History*, (London: Athlone, 1988) p. 67.

[37] Leonard N. Rosenband, "Becoming competitive: England's Papermaking Apprenticeship, 1700-1800" in Lissa Roberts, Simon Schaffer, and Peter Dear (eds.) *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation* (Amsterdam: Edita KNAW, 2007), pp. 379-401.

writing support it finally became.[38] Moreover, the migration of artisans facilitated the early circulation of know-how within and outside the Italian context. Finally, the production of paper contributed to its diffusion through export.[39] In the early modern period, the time advantage of Italy had been levelled out and the art of papermaking was widely spread throughout the continent, from France to Spain, Germany, and later the Netherlands and England.

Although the art of paper production gradually reached every country in Europe, its manufacture in Genoa still retained a substantial primacy between the 16th and 18th centuries. That production was carried out in proximity to the port city was important and, despite competing with other European countries in the continental market, Genoa's high-quality paper guaranteed its significant position as a major exporting state. Therefore, while by 1690 the first corporation of producers in England, mostly comprising newly settled French, was negotiating a monopoly for manufacturing white paper and prohibiting the export of rags, the production in Genoa was almost at its peak.[40] From the data on the sole district of Voltri, Genoa's largest one, it has been estimated that its 80 operative mills were producing an annual amount of 240,000 reams ca. of writing paper only. Such a remarkable quantity of paper was mostly destined for export and was due to increase further as more mills were built around Genoa by the 18th century.[41] Genoa's case, therefore, is a representative one to consider in this context of exchange with the English manufacture within the European perspective. What makes such Italian case more relevant here, though, is the reasons for its extraordinary productivity, which constituted its distinction and the earliest rationalised model of paper's large-scale production in Europe.[42]

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[38] Richard L. Hills, "Early Italian Papermaking: A Crucial Technical Revolution." in Simonetta Cavaciocchi (ed. by), *Produzione e Commercio della Carta e del Libro, secc. XIII–XVIII,* (Firenze: Le Monnier, 1992) and Richard L. Hills, "A Technical Revolution in Papermaking, 1250-1350", in John Slavin (ed. by), *Looking at paper: Evidence and Interpretation*, (Ottawa: Canadian Conservation Institute, 2001), pp. 105-111.

[39] Giancarlo Castagnari, "Le origini della carta occidentale nelle valli appenniniche delle Marche centrali da una indagine archivistica", in Giancarlo Castagnari, Emanuela Di Stefano, Livia Faggioni (eds.), *Alle origini della carta occidentale: tecniche, produzioni, mercati (Secoli XIII-XV)*, (Fabriano: Istocarta, 2014), pp. 9-34.

[40] D. Coleman, *The British Paper Industry,* pp. 68-72.

[41] The amount of paper produced in Voltri could be considered from the data provided by Calegari. He states that the medium production of a local mill between 1588 and 1612 is 300 bales per year. He also informs us that in Voltri in 1690 there were 80 mills. We can estimate then that in the sole area of Voltri by the end of the 17th century at least 24.000 bales of paper were produced. Considering that each bale contained 10 reams we have an annual production at Voltri mills of 240,000 reams. Manlio Calegari, *La manifattura genovese della carta: (sec. XVI-XVIII*), (Genova: ECIG, 1986) pp. 5, 57.

[42] Renzo Sabbatini, *Di bianco lin, candida prole: La manifattura della carta in età moderna e il caso Toscano* (Milano: Franco Angeli, 1990).

3. The Italian case: Genoa

3.1 Genoa's model of paper production and the rise of merchant entrepreneurs

It is often reported that Genoa's manufacture of paper around the 17th century underwent an exponential development. In the sole area of Voltri the number of paper mills soared from the 20 operating during the 16th century to 87 in the 17th and more than 150 in the 18th century.[43] Manlio Calegari, who studied that growth in detail, researched the foundations of such a development and indicated how the financial involvement of a group of merchant entrepreneurs had distinctively shaped the whole manufacture. He noted that, until the first half of the 16th century, the manufacture of paper in Genoa was diversified, in that it relied on various forms of agreement between master papermakers, labourers and the owners of the means of production. By the end of that century significant investments provided by a class of affluent merchants flowed into the manufacture. As a result, the number of paper mills started to grow with new edifices uniformed to a standardised system of production, which historiography now sees as the core of what has been named as "Genoa's model". [44] The merchants' regime was comprehensive and far-sighted, certainly reflecting the emerging interest and understanding of crafts by the aristocratic elites.[45] They heavily invested in newly built and more efficient mills, also securing their workforce through a standardised type of contract that strictly regulated the craftsmen's activities.[46] As a consequence of their intervention in the manufacture, each aspect of the production underwent a process of rationalisation. The productive system that they introduced allowed them to precisely estimate investments and amortisation times.[47] The result of that development was the complete control of merchants over the paper manufacture and their dominating position over master papermakers, which we are going to clarify through a contemporary source.[48]

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[43] Paola Massa, "La gestione tecnico-organizzativa di un "edificio da carta" a metà Seicento" in Pietro Cafaro, Giuseppe de Luca, Andrea Leonardi (eds.), *La storia economica come impegno. Studi in onore di Angelo Moioli*, (Milano: FrancoAngeli, 2015) pp. 45-65, p. 45.

[44] Renzo Sabbatini, *Di bianco lin candida prole*. pp. 224-227. Sabbatini indicated Genoa's model as an influential manufacturer for the production of paper within the continent in the following centuries. Renzo Sabbatini, "Cartai e cartiere", in Philippe Braunstein and Luca Molà (eds.) *Il Rinascimento Italiano e l'Europa: Produzione e tecniche*, Vol 3. (Treviso: Fondazione Cassamarca, 2005) pp. 387-403, p. 402.

[45] That pursuit of efficiency for the paper manufacture was the cultural result of the integration of practical knowledge into the written and learned tradition. See: Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600*, (Corvallis: Oregon University Press, 2011).

[46] M. Calegari, *La manifattura genovese della carta*, pp. 21-25.

[47] M. Calegari, *La manifattura genovese della carta,* p. 10.

[48] M. Calegari, *La manifattura genovese della carta,* p. 7-9.

The literature usually indicates a handbook on commercial trade as an important source of information about that model of production. This is a 1651 volume written by the Genoese businessman and publisher Giovanni Domenico Peri (1590-1666). Peri's manual was comprehensive and covered what any successful merchant entrepreneur in Genoa had to know for establishing a prosperous business, from the practices of accountancy to the practicalities for starting one of a most profitable local manufacturing products: that of paper. Profit was clearly at the core of Peri's instructions, which required detailed premises. The site for a new mill had to be pondered accurately in order to make the most of the energy supply provided by the mountains' steep streams, clean water and the flow of the Tramontane and Ponente winds, ideal for drying paper.[49] Moreover, the construction of the building had to follow precise dimensions and a standard plan for a three storey edifice, which was also meant to house the master papermaker.[50] From Peri's description we understand that, within those mills, nothing was left to chance and each activity had a dedicated space.[51] In conformity with the standards that Peri defined, he indicated that a certain output was to be expected, whether as a daily or yearly yield, expressed in the number of bales of paper produced from a standard unity of rags.[52] The author also provided the involved details about the contract to be agreed with the workforce, which was the key for profit. The master papermaker had to receive a weekly advanced payment that constituted his credit and was meant to be redeemed when the production was handed to the merchant, therefore representing for the artisan a binding obligation. The agreement required master papermakers to produce at least a required minimum yield from a certain amount of rags.[53] The merchant, on his side, had to provide tools and raw materials, but maintained commercial rights over the entire production, including any eventual surplus. However, Peri specified, the merchant was expected to remunerate masters at a slightly higher rate for any surplus, but in case a papermaker was found to contraband any remaining production, he could have faced severe penalties.[54]

Paper historians acknowledged the accuracy of such an account and confirmed through documentation that, far from being a literary generalisation, Peri's voice vividly pictured the core elements of Genoa's model.[55] Nonetheless, although well known, the account has often been considered only for the content of that description. Peri's handbook, however, is evidently

[49] Giovanni Domenico Peri, *I frutti d'Albaro*, (Genova, 1651) p. 64.
[50] G. Peri, *I frutti d'Albaro*, p. 65.
[51] G. Peri, *I frutti d'Albaro*, p. 65.
[52] G. Peri, *I frutti d'Albaro*, p. 70.
[53] A minimum production expected from a certain amount of rags was determined under the corporative regulations.
[54] G. Peri, *I frutti d'Albaro*, p. 70.
[55] Paolo Cevini, *Edifici da Carta Genovesi, Secoli XVI- XIX*, (Genova: Sagep, 1995) pp. 147-148, See also: Conor Fahy, "Paper Making in Seventeenth-Century Genoa: The Account of Giovanni Domenico Peri (1651)", *Studies in Bibliography*, 56, 2003. pp. 243-259.

more than that. It is also a testimony to a much deeper connection between the manufacture of paper itself and Genoa's intrinsic culture of paper.[56] By stating in his handbook that "everything by means of paper is easily rendered and brought to accomplishment", Peri openly revealed that paper had significantly shaped Genoa's development. It was not by chance, indeed, that a detailed account of the manufacture of paper was included in a manual on accountancy, which extensively discussed the good practice of merchants carried out on that same paper they produced, from double entry to the compilation of registries and bills of exchange. Richard Goldthwaite studied how in Italy, by the late 16th century, the medieval practice of accountancy had been refined and Florentine manufacturers started to better trace their finance by combining in a single ledger what was previously reported in several ones.[57] That change is possibly the reason for the growing prominence of the accountancy book in the portraiture of 16th century merchants that Basil Yamey observed.[58] Being essential equipment for control, merchants' papers were apparently becoming the most representative attribute of their trade. Goldthwaite states that such an improvement in accountancy does not authorise us to recognise the practice as an actual "capitalist instrument", since at that time it did not entail a "conscious ideology" yet.[59] However we may wonder whether that consciousness was emerging in the 16th and 17th centuries as a consequence of that more efficient use of paper support and whether we should trace the realization of that awareness in Peri's statements. Merchants in Genoa, as we can infer from the author, were indeed consciously articulating the reason for profit over expense through the medium of paper and applied that same logic to paper's systematic model of production. Therefore, what the focus of historiography neglected to highlight is that, for Peri, paper in Genoa was not just the mere product of the local manufacturer, but also the compelling means by which merchants were able to estimate profits and take full control of the efficiency of their enterprises.

3.2. Genoa from the lead to a new phase

As historians explored the large documentation on Genoa's case through its copious archives, a wider picture of the manufacture of paper has been traced. This is now essentially

[56] The role of paper in the development of Genoa has been suggested in a study that indicated how the early use of the less expensive writing support of paper, in comparison to parchment, went to shape the complex protocol of notaries, who formalised innumerable aspects of people's life. See: Armando Petrucci, *Writers and Readers in Medieval Italy: Studies in the History of Written Culture,* (New Heaven: Yale University Press, 1995) pp. 153-7.
[57] Richard Goldthwaite, "The Practice and Culture of Accounting in Renaissance Florence", *Enterprise & Society*, vol.16, no.3, 2015, pp. 611-647, pp. 629-630.
[58] Basil Yamey, *Art & Accountancy*, (New Haven: Yale University Press, 1989) pp. 19-33
[59] R. Goldthwaite, "The Practice and Culture of Accounting", p. 639.

outlined as a parabola from its inexorable rise through the 17th century to a slow decline in the late 18th century. Some contextual elements were critical in determining the growth of Genoa's paper manufacture to the scale reached at its apex. As mentioned earlier, Peri advised entrepreneurs to wisely select the locations for their mills according to favourable winds, clean water and waterpower. Indeed, the Apennine Mountains offered countless ideal sites nearby its numerous streams. Genoa's paper manufacture developed along them through five main districts, of which Voltri was the main one, where many mills found their place for the distinct production of white paper and, in lesser number, of browns.[60] The surrounding mountains, besides, provided much more than wind and water: they were abundant in other resources such as timber and metals, indispensable for supplying mills with the necessary materials and tools.[61] The proximity to Genoa's commercial harbour was also key. Paper, indeed, was exported through the same busy seafaring trade that guaranteed the constant importing of rags from the various commercial destinations. The social factor constituted an additional value to the development. Settlements grew around mills and new communities were established, where entire families were involved in paper manufacture.[62] The kin of male workers commonly undertook all the auxiliary tasks, equally determinant for the success of the enterprise, such as unstitching hems and ripping rags, a typical female job, or hanging paper to dry, ideally executed by children's little hands. By undertaking those tasks, considered to be the unskilled ones, entire families provided merchants with a valuable and profitable low-cost workforce.[63] As a contemporary concisely described it: "countless souls in Voltri and its surroundings are managed in the paper mill, merchants make a profit as the others make their living".[64] Those "countless souls", however, had to indicate not only the manpower directly employed within the mills, but also those who worked conjointly with the papermaking activity. The rising number of mills had to require the work of many specialists, such as mould makers, carpenters, and masons. Merchants who invested in the manufacture of paper, it has been considered, benefited from that varied network of local workforce, which provided low cost labour as well as professional competences.[65] Within that complex network of people laid an important factor

[60] The paper district comprised Pegli, Voltri, Cogoleto, Arenzano e Varazze, see: Paola Massa, "Tipologia industriale e modelli organizzativi. La Liguria in età moderna", in Simonetta Cavaciocchi (ed. by), *L'impresa, industria, commercio, banca secc. XIII-XVIII*, (Firenze: Le Monnier, 1991) pp. 481-502, p. 487. On the specific case of mills for brown paper see: P. Cevini, *Edifici da Carta Genovesi,* pp. 188-192.

[61] P. Massa, "Tipologia industriale e modelli organizzativi", p. 487.

[62] See the case of "Fabbriche": a new village born in 1610 around the mills. P. Cevini, *Edifici da Carta Genovesi,* p. 148.

[63] M. Calegari, *La manifattura Genovese della carta*, pp. 11, 144.

[64] "Nella fabrica de paperi (…) si governano infinite anime del loco di Voltri e circumstantie", M. Calegari, *La manifattura Genovese della carta*, p. 14.

[65] Ibidem.

of Genoa's model concerning the know-how of paper's manufacture. The key of papermaking could hardly be confined to the few who worked around the vat, as the art entailed a complex and distributed range of competences and knowledge requiring the work and proficiency of many. In conclusion, the reason for the success of paper manufacture in Genoa was a combination of social and environmental factors: a conjuncture that had developed gradually with the art itself. Such a combination was conceivably hard to find or even reproduce promptly anywhere else.[66]

The literature has also suggested that, underneath the remarkable productivity determined by Genoa's distinctiveness, such a model harboured some problems. These are indicated as the long-term costs of an established rigid system which was destined to bring the paper manufacture into decline. The restrictive terms imposed by merchants on the workforce generated innumerable violations, admonishments and social conflicts, all explored in detail by the literature through the documents.[67] The implications of such an intense productive model, therefore, have been suggested to be at the origin of a stasis of innovation. Calegari has especially studied that aspect, indicating the main factor in the thorny position of masters. [68] These had become part of a system in which their role was merely that of salaried workers. According to Calegari's reading of the facts, papermakers had, indeed, very little interest in innovation. He observed that their unique reason for improvement was limited to the increase in income coming from the delivery of the surplus to merchants. To support his analysis, Calegari explained how masters, instead of innovating, were prompted to excogitate several expedients in order to increase the yield from rags. He thus reported from the relative documents of charge that some masters were adding lime to the process in order to raise the weight of paper, while others introduced filters into the drains of cleaning tubs, therefore retaining any possible discharge of fibres from rags, but also holding impurities.[69] Despite being penalised, however, those strategies were apparently extremely effective as the yield grew significantly between the 16th and 18th centuries.[70] To further sustain his argument on the stasis of innovation, Calegari mentions the general refusal to introduce the Hollander engine, inferring that the novel device would have determined a cost for the merchant, whereas they possibly considered it as not having any significant immediate benefit.[71] From such analysis we gather that Calegari's idea of

[66] The Tuscan case, as studied by Sabbatini, is emblematic of that difficulty since it was unsuccessfully modelled on the Genoese example. Renzo Sabbatini, *Di bianco lin, candida prole,* pp. 224-227.
[67] M. Calegari, *La manifattura Genovese della carta*, pp. 65-72.
[68] M. Calegari, *La manifattura Genovese della carta*, pp. 103-107.
[69] M. Calegari, *La manifattura Genovese della carta,* pp. 105-106.
[70] It is necessary to specify that the minimum yield fixed by contracts between merchants and masters grew too accordingly through the time. M. Calegari, *La manifattura Genovese della carta,* p. 63.
[71] M. Calegari, *La manifattura Genovese della carta,* p. 111.

innovation merely concerned the adoption of new mechanised systems. While he acknowledged that papermakers were absorbed in developing technical strategies to increase the yield, he did not include those expedients in the span of innovations. Those techniques, however, clearly required a high level of mastery over the art. They denoted an extremely adaptable knowledge of the entire process and testify to a successful experimentation on paper's matter at its core: one that was leading them to explore some potentialities offered by working directly on the fibrous substance. Although cornered in the productive system, masters still exercised their know-how resourcefully and effectively. It was in that fertile environment of artisanal knowledge that, as will be explained in the course of the thesis and in the 5th chapter in particular, I have been able to locate an influential novelty for the future developments of paper and a crucial case of exchange with the elite of naturalists: the first formulation of a paper made out of the mineral fibres of asbestos.

Whereas Genoa's case denotes a certain vitality of artisanal ingenuity, nonetheless the missed adoption of new technologies, as remarked on by the literature, at some point had to impact the expansion of its manufacture. In the 18th century, the competing productions of France, England and Netherlands had grown significantly to supply their respective domestic markets.[72] The consequent slowdown in trade brought an initial drop in production in Genoa, in conjunction with a sudden rise in the cost of rags. Data reveals that, by the second half of the 18th century and for the first time, the overall number of mills decreased as some of them ceased their activity. The historiography agrees in indicating that century as marking the conclusion of Genoa's extraordinary phase of growth in the manufacture of paper. [73] It was possibly that reversal in the trend, however, that offered to Genoa's papermakers a late opportunity for a different development. As merchant entrepreneurs eased their interest in paper's manufacture, new figures of masters emerged who owned their own mills.[74] By 1792, possibly because of that change and in reaction to the new varied demands of the markets, the assortment of specialised low-quality papers increased and, albeit with a reduced production, innovation was more dynamically pursued, as attested to by a rare recipe book that has been recently studied.[75] By then, Genoa's most significant expansion had ended its course, having expressed the potentialities offered by its form of the proto-capitalist enterprise of papermaking. The rationalised model of production developed in that Republic, however,

[72] P. Massa, "La gestione tecnico-organizzativa" p. 45.
[73] M. Calegari, *La manifattura Genovese della carta*, pp. 166-167.
[74] P.Cevini, *Edifici da Carta Genovesi*, p. 69.
[75] The "Scartafascio di Mele" is the rare recipe book of a papermaker who worked in Mele in the 19th century. The document contains detailed recipes and relative paper samples. See: Elisabetta Badia, *Metamorfosi di un processo artigianale nell'Ottocento: Lo Scartafascio di Mele*, Tesi di Laurea, 2010, Università degli Studi di Genova.

allowed other foreign manufacturers to foresee paper as the future mass commodity it later became.[76] Since then, however, some major developments in the mechanization of the papermaking process started to unfold far from Italian paper mills.

4. The English Case

4.1 The slow beginning of the English manufacture of paper

Considering the early role of Italy in the European export of paper, it is not surprising that the earliest paper in use in England since the 14th century came from Genoa. Based in Southampton since the Middle Ages, Genoese traders exchanged a variety of goods with local merchants, including paper.[77] Such an enduring commercial relationship implied more than a simple trade in goods. Although some researches revealed that English born craftsmen and labourers were not unusual among those active in Genoa since the Middle Ages, the presence of the Genoese in England, especially in connection with papermaking, is apparently very difficult to trace.[78] That active exchange, however, may provide a contextual factor to the result of a study on the first printing paper produced in England. Made in Hertford at the end of the 15th century in the mill of the former merchant John Tate (c. 1448-1507), some samples of that paper survived and have been subject to the meticulous analysis of the bibliographer Allan H. Stevenson. [79] By considering the distinctive spacing among the chain lines left by the moulds, and the intersection of the watermark's thread, Stevenson concluded that the mould-maker, who designed for Tate a distinctive Tudor rose watermark, was probably a Genoese craftsman.[80] Considering that there was such a long lasting commercial trade, that information is revealing. The importing of paper might, at some point, have spurred the emergence of internal production. The evidence put forward by Stevenson's study suggests that, in order to pursue such a target, the connection with Genoa had been determinant. Although we don't know more

[76] R. Sabbatini, "Cartai e cartiere", p. 402.
[77] Alwyn Ruddock, *Italian Merchants and Shipping in Southampton* (1270-1600), (Southampton: University College, 1951) p. 41. Orietta da Rold, "Materials" in Alexandra Gillespie, Daniel Wakelin, (eds.) *The Production of Books in England 1350-1500*, (Cambridge: Cambridge University Press, 2011), pp. 12-33, p. 24.
[78] Several studies have explored the active presence of English workers is Genoa since the Middle Ages: Roberto Sabatino López, "The English and the Manufacture of Writing Materials in Genoa", *The Economic History Review*, X, 1940, pp. 132-137, Federico Meda, "Tra Genovesi e Inglesi nel basso medioevo (XII-XIV), *Studi Genuensi*, V, 1987, pp. 35-43. Robert Reynolds, "Some English Settlers in Genoa in the Late Twelfth Century", *The Economic History Review*, IV, 1932-34, pp. 316-321.
[79] Allan Henry Stevenson, "Tudor Roses from John Tate", *Studies in Bibliography*, Vol. 20, 1967, pp. 15-34. On Tate see: R. L. Hills, *Papermaking in Britain 1488-1988,* p. 5.
[80] A. Stevenson, "Tudor Roses from John Tate" pp. 20, 26.

about that specific circumstance, we can infer that the exchange between Genoa and England was of a fertile nature. It had to entail the transition of not only goods, but also people and, with them, their relative competences and even equipment.

In just a decade Tate's initiative was over, yet it marked an important step for domestic papermaking. His contemporaries acknowledged an intrinsic value in Tate's enterprise. His mill received a royal visit by Henry VIII and, in 1495, the printer Wynkyn de Worde (d. 1534) praised it as the source of the first English-made paper.[81] Despite its short duration, that venture had to set a precedent and, although historians today rely on scant documents, it is very likely that a very first generation of English papermakers were trained back then. The information on the subsequent development of papermaking is inconsistent. In 1585, Richard Tottyl (d. 1594), a London stationer, planned to set up the new manufacture of white paper employing French labourers, unsuccessfully petitioning for a monopoly. On that occasion, Tottyl appealed to the national interest by remarking on the loss derived from the importing of paper made in France with English rags.[82] In other words, his petition requested to ban the export of rags in order to secure his business. As historians know well, the shortage of linen rags had long been an endemic drawback for English papermakers. In that sense, Tottyl's statement is significant, since it explicitly raised that problem for the first time.[83] The same difficulty was still a cause of concern when, a few years later, in 1588, John Spilman (c. 1552-1626) a German jeweller to Queen Elizabeth I, decided to invest in the business of paper and was granted a monopoly, which expressly included the collection of rags.[84] At his own expense, two mills in Dartford were repaired and converted to make paper with the know-how of workers and expertise from Germany.[85] More than for Spilman's own enterprise, however, the case is relevant for the reaction aroused by the rights granted with such an extensive monopoly. Indeed, the privilege did not only establish an exclusive right over the collection of linen rags "for making all sorts of white paper". Spilman was also entitled to collect different materials such as old fishing nets, which were regularly used for the lowest qualities of paper. That provision meant that any producer of browns was subject to Spilman's licence in order to run the activity in his own paper mill.[86] As a result, a conflict over the collection of rags emerged in 1601. The authorities of the City of London had to acknowledge that other mills had been actively producing paper before Spilman, while he complained about being forced to make brown paper as a result of other

[81] Bartholomaeus Anglicus, *De proprietatibus rerum*, ed. by Wynkyn de Worde, (1495). For the transcription of the text see: D. Coleman, *The British Paper Industry,* p. 40.
[82] D. Coleman, *The British Paper Industry,* pp. 40, 52.
[83] D. Coleman, *The British Paper Industry,* p. 53.
[84] Rhys Jenkins, *Papermaking in England, 1495-1788*, (London: Association of Assistant Librarians, 1958) pp. 7-11.
[85] D. Coleman, *The British Paper Industry,* p. 44.
[86] D. Coleman, *The British Paper Industry,* pp. 47-48.

manufacturers competing with him in the collection of white rags.[87] The documentation issued in that circumstance suddenly offered historians a wider perspective on the varied landscape of the emerging British trade of papermaking: an evidence consistent with the first seminal research by Alfred Shorter on this same topic.[88]

4.2 The English brown paper

Shorter's research explored an alternative narrative. Diverging from the focus on the achievement of white paper's manufacture analysed by the mainstream literature, his study engaged with a meticulous investigation on the sparse documentation from local archives and the traditional names of localities.[89] His painstaking work revealed that, by 1650, at least 38 paper mills were active in England, scattered across a considerable number of counties, from Kent to Devon and the farthest regions from London, north Lancashire and Yorkshire.[90] A more complete picture of the English manufacture of paper started to emerge, delineating the traits of a rural activity concerning a paper production of low qualities, mostly for wrapping and packaging purposes.[91] Such production was carried out in ordinary mills that had been converted from other manufacturing tasks, such as fulling or grinding grains.[92] The English paper mills, therefore, were flexible sites, significantly different from those expressly designed around the same dates in Genoa. Papermaking in those sites could replace a decaying manufacturing activity just as it could be supplanted by another activity upon necessity.[93] The conversion of mills is what determined the most distinctive trait of English paper manufacture scattered in remote locations, with the sole exception of the productive sites closer to London, mostly concentrated in Buckinghamshire and Middlesex. What we know of those mills and the production carried out by their respective manufacturers is very limited, yet significant. The intellectual John Evelyn (1620-1706) included in his "Diary" some information about the activity of a paper mill operating in Surrey in 1678.[94] Typical of his wide-ranging interest on things, Evelyn indicated the presence in the mill of a diverse assortment of raw materials mentioned as

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[87] Alfred H. Shorter, *Paper Mills and Paper Makers in England, 1495-1800,* (Hilversum: Paper Publications Society, 1957), p. 29. For a more recent and comprehensive study of such a case see: John Noel Balston, *The Elder James Whatman: England's greatest paper maker (1702-1759),* (London: Balston, 1992), pp. 17-18.
[88] For a collection of Shorter's works: Richard L. Hills (ed. by) *Studies on the History of Papermaking in England/ Alfred H. Shorter*, (Aldershot: Variorum, 1993).
[89] A. Shorter, *Paper Mills and Paper Makers in England.*
[90] A. Shorter, *Paper Mills and Paper Makers*, p. 29.
[91] A. Shorter, *Paper Mills and Paper Makers*, p. 30.
[92] R. Hills, *Papermaking in Britain 1488-1988: A Short History,* p. 50.
[93] Ibidem.
[94] John Evelyn, *Diary*, vol.2, William Bray (ed. by) (London: Dent, 1937), p. 125. D. Coleman, *The British Paper Industry*, p. 56.

"linen for white paper" and "woollen for brown". That detail appears consistent with the mill's production, which he described as a "coarse white paper". Evelyn's account apparently did not represent an atypical case. Shorter, indeed, informs us that the production at that time mostly comprised brown paper and "whited brown". That production, according to the historian, was the result of the activity of the large number of mills processing a variety of coarse materials such as ropes, netting and bagging, with even wool rags for the lowest qualities.[95] However, the relevance of Evelyn's words more interestingly concerns not just the paper produced there but rather the fact that poor raw materials, such as wool rags, were processed with the most valued linen rags in the same edifice. Such a practice, indeed, had to establish a praxis and the inventory of a mill in Sutton-at-Hone, Kent, confirms its consistency. Penned in 1710 to assess the repossession of a papermaker's belongings, the document enlisted the expected equipment for making paper, with the significant indication of two piles of felts, respectively indicated as "black" and "white".[96] The presence of those felts, clearly destined to switch the production between white and brown paper according to the raw materials available, is an important factor to consider. It indicates that the practice was carried out under the same roof. More significantly, it also implies that the Kentish papermaker, by virtue of necessity, was dealing with a large assortment of materials.

Historians now generally agree that the end of the 17th century was a phase of induction for the forthcoming growth of paper's manufacture in England.[97] The proficiency of the art, in that period, was in the process of fine-tuning and the production of browns, being a founding trait of the domestic manufacture, was at its origin. Some have indicated the signs of a development in the diversification of products during the second half of that century. This, in particular, concerned the right granted over the manufacture of blue wrappings, along with some patents for improving the processing of pasteboards and sheets suitable for pressing cloths.[98] Significantly, those cases barely related to the production of white writing paper. The impulse for advancement also concerned the attention for new technology.[99] In 1682 a patent was granted over an "engine" for the more efficient processing of "all sorts of materialls", such as hemp, flax, cotton, linen, silk and wool for whatever purpose.[100] In that case historians have ruled out the possibility of a very early introduction of the Hollander for grinding rags more

[95] Alfred H. Shorter, *Water paper mills in England*, (London, Society for the Protection of Ancient Buildings, 1966) pp. 3, 8-9.
[96] L.R.A. Grove, "Inventory of a Sutton-at-Hone paper mill in 1710". *Archaeologia Cantiana*, vol. LXXII, 1959 pp. 230-233., p. 232.
[97] J. Balston, *The Elder James Whatman,* p. 6.
[98] Alfred H. Shorter, *Paper Making in the British Isles. A historical and Geographical Study*, (Newton Abbot: David & Charles, 1971), p. 23.
[99] Ibidem.
[100] Ibidem. On the development at these dates see also: D. Coleman, *The British Paper Industry*, pp. 59-63.

quickly and in larger quantities, compared with traditional stampers. Nevertheless, such an interest in improving processes is certainly indicative of a vital phase of receptiveness.[101] That trait appears, therefore, in sharp contrast with the rigidity of Genoa's paper manufacture at its most intense phase of production.

4.3 The growth between brown and white paper

Historiography indicates that, by the late 17th century, the manufacture of white paper in England also advanced significantly.[102] In 1686, a group of investors, Huguenots who had recently taken refuge from France, formed the Company of White Paper Makers and undertook the conversion of a number of mills employing foreign skilled workers, mostly from their country of origin.[103] French labourers, joined by some Dutch, worked in close collaboration with the English staff, which certainly guaranteed a vital exchange of competences. Although the activity of the company concluded before the end of the century and the quality of the paper produced was apparently not remarkable, the influx of foreign skilled labourers clearly fostered a dissemination of know-how about white paper beyond their respective domestic boundaries.[104]

At this point it is necessary to highlight that the studies of English papermaking demonstrate a preponderant emphasis on the historical events concerning the production of white paper. This was in part inevitable due to the scant documentation on the manufacture of browns. That fact, indeed, clearly reflects a bias coming from the primary sources. In comparison with browns, white paper was more highly valued as a commodity and a more profitable good for both manufacturers and traders. Consequently, it required regulations and controls over a more limited supply of raw material; and this is also a reason why most of the documentation on paper manufacture concerns white paper. Moreover, the long-chased production of paper of that quality was seen with a sense of achievement. We have seen how, since the time of John Tate's first printing paper ever made in England, such enterprise was hailed with national pride. All these elements may have led historians to underestimate the impact of the production of paper of low qualities. Nonetheless, it has been noticed, the essential proficiency required by craftsmen who produced white or brown paper did not diverge significantly and English papermakers had somehow to master their art in order to switch

[101] R. Hills, *Power from Wind*, pp. 182-191.
[102] D. Coleman, *The British Paper Industry*, p. 87.
[103] George H. Overend, "Notes upon the Earlier History of the Manufacture of Paper in England", *Proceeding of the Huguenots Society of London*, Vol. VIII, 1906, pp. 201-217 and John H. Thomas, "Hampshire and the Company of White Paper Makers", *Proceeding of the Hampshire Field Club and Archaeological Society*, vol. 26, 1970. pp. 137-148, p. 143.
[104] J. Balston, *The Elder James Whatman*, p. 11.

between the two types, often merging them.[105] John Balston, who likewise studied the development of the white paper industry, discussed such a technical observation to support the argument that the English manufacture of white paper had actually started to develop before the experience of the Company founded by the Huguenots.[106] He stated that the actual origin of the English art of white paper laid in the hands of those manufacturers of browns and whited brown papers who, despite being virtually able to make white paper, were mostly impeded by the unescapable shortage of suitable rags. While Balston's argument, with regard to the development of white paper, is reasonable, I argue that the implications of such a reflection are wider than his primary target.

As we have seen, although many of the raw materials for paper of low qualities such as wool or hemp were known in other manufacturing, the established practice required that they had to be processed in mills with different features, resulting in two well distinct productions.[107] The English practice of constantly dealing with a wide range of raw materials within the same mill, as in the case of the Kentish papermaker previously mentioned, meant papermakers had to generate a distinctive skill to flexibly master the art of papermaking from a range of fibres. Such a practice is meaningful, since it conflicted with the conventional separation of distinct mills for the respective production of white and brown paper that was customary in Genoa, as well as among the most advanced paper manufacturers.[108] In England, it has been clarified, such a partition was virtually inapplicable due to the limited supply of linen rags.[109] We may say that such a trait for the English paper manufacturer, derived from a drawback due to the local resources, established a know-how that is not to be underestimated in the light of the subsequent developments. That practice had to raise an awareness of the way different raw materials combined and how they resulted through the process of papermaking.

Despite the scant documentation, it is possible to find some evidence of the range of browns or whited brown papers in the English archives, when the accuracy of conservators prevented their loss. This is the case with a coarse brown paper, used to wrap the wax seal of a 1679 deed (fig. 1.2a). That scrap of paper presents some black lumps derived from the

[105] J. Balston, *The Elder James Whatman*, pp. 12-13.
[106] J. Balston, *The Elder James Whatman*, pp. 13-15.
[107] Jerome de Lalande, a main source for the 18th century manufacture of paper in France, dedicated to the white paper craft and brown two distinct works: Joseph Jerome de Lalande, *Art de faire le papier* (Paris, 1761) and Joseph Jerome de Lalande *Art du Cartonnier* (Paris, 1762).
[108] As documents always specify their type, white and brown mills were two distinct edifices in Genoa's paper manufacture. See: P. Cevini, *Edifici da Carta Genovesi*, pp. 188-192. In order to guarantee the uniform higher quality of white paper, in Colle Val d'Elsa, Tuscany, indistinct productions in the same mill were expressly prohibited. Carlo Tosi, "Capitoli sopra l'arte della carta a Colle", in Comitato scientifico per l'allestimento del Museo della lavorazione della carta (ed. by), *Carta e cartiere a Colle, miscellanea di studi*, (Firenze: Baccini & Chiappi, 1982), pp. 27-65, pp. 40-41.
[109] J. Balston, *The Elder James Whatman*, p. 6.

processing of tarred ropes, which typically left the visible fragments of pitch entangled in the hemp fibres (fig. 1.2b). Similar examples of brown paper, which could be used as an ordinary cover for notebooks, had to be common (fig. 1.3a, 1.3b). Another wrapping shows what "whited brown paper" possibly meant: in that case, the coarse paper appears less dull than the examples of browns (fig. 1.4a, 1.4b). These examples testify to a flexibility of practice that deserves to be considered as a distinctive trait of English ingenuity: one that should be especially appreciated in the light of the rigidity of the craft in foreign countries at that time. That production was, after all, nothing less than the expression of a necessity for the domestic paper manufacturer: an adjustment of the conventional process of papermaking for the more varied sources of fibre-based materials available. The qualities of those wrappers had to constitute the origin for a distinctive low-quality printing paper, used for some ordinary ballads from the end of the 18th to the middle of the 19th centuries, in which the entanglement of stalk fibres and impurities reached an extreme limit of fitness for purpose (fig. 1.5a, 1.5b). All the examples considered contribute to delineate the material context in which the experimentation of Matthias Koops and his dignified straw paper was taking place.

4.4 Towards the industrial advancement

By the turn of the 17th century, paper had gradually become a widespread commodity. The English paper manufacture, in response to the rising demand for that good, underwent a significant change.[110] Some favourable conditions facilitated the new development. Through the records of the excise duties, introduced in 1696, Coleman was able to trace a clear policy of protectionism. In the long term, that taxation benefited the domestic manufacturers against imports, especially from France.[111] Moreover, during the War of Jenkins' Ear and that of the Austrian Succession (1739-1748) the importing of paper from the Continent was impeded, giving a further significant stimulus to the local industry.[112] At the same time, the duty free tariff applied to rags encouraged their rising import, while the parallel growth of the domestic linen industry might have guaranteed some internal supply of raw material.[113] Finally, in relation to the availability of rags, historians have apparently overlooked the impact of the industrious

[110] Coleman described the time after the Civil War as a phase that "unlocked the flood-gates" to a stream of tracts and publications along with periodic news-sheets such as the London Gazette. See D. Coleman, *The British Paper Industry*, p. 9.
[111] D. Coleman, *The British Paper Industry*, pp. 64-68.
[112] Theresa F. Harris, Michael Fuller and Maureen Green, "Papermaking and the Whatmans" in Theresa Harris, Scott Wilcox (ed. by) *Papermaking and the Art of Watercolour in Eighteenth Century Britain: Paul Sandby and the Whatman Paper Mill* (New Haven, London: Yale University Press, 2006) pp. 79-84, p. 79.
[113] D. Coleman, *The British Paper Industry*, pp. 106-108.

involvement of Jews, who had been readmitted in England in 1655.[114] The trade of old cloths among the poorest of them, in the 18th century, turned the sporadic activity of rag picking into a profession as they gradually took an active part in London's busy life.[115]

The first half of the 18th century was a crucial time for the manufacture of paper that cannot be better illustrated than by the figure of James Whatman (1702-1759), whose enterprise achieved, with the "wove paper", a significant innovation in the European progression of papermaking. The case has been comprehensively studied by John Balston, who started to analyse the episode from the broader context of Kent, where a significant number of mills ventured into the manufacture of paper in the same round of years.[116] That context is significant to comprehend the circumstances for that innovation to take place. Analogously to the way Genoa's paper manufacture had evolved and thrived in districts, the productive area of Kent in the 18th century was developing an advanced know-how of papermaking. Other determinant elements concerned the personal background of James Whatman, along with his initiative as an affluent descendant of a master tanner. According to Balston, Whatman in his youth was kin to a family of papermakers and acquired the knowledge of that craft abreast of a peer in his relatives' network, Richard Harris, who had received decisive training in the Netherlands.[117]

In 1733 Whatman committed to invest in an independent business and, counting on Harris' proficiency, the two rebuilt a small mill in a remote location. After a few years of activity they gained experience with a new Hollander engine, which had recently been introduced from the Netherlands in some English mills with inconsistent results.[118] Operating a large roll, the engine rapidly ground a large amount of raw material, which means that, conversely to the traditional slow system of stampers, the process could not be constantly assessed whilst running. Moreover, it was not only a powerful and complex machine to operate but it also required to be adapted to different conditions than those in which the system was first invented. Therefore, in order to master its operation, papermakers needed to gain a certain experience.[119] The proficiency acquired in that first project, according to Balston, was a determinant for Whatman and Harris to embark on a much bigger plan at Turkey Mill in Maidstone with the confidence to succeed over other contemporary ventures. Another factor was notable. Turkey Mill had

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[114] On the industrious activity of rag picking in Italy see: Bernardino Ramazzini, *De Morbis Artificum Diatriba*, (Modena, 1700) pp. 241-247.

[115] By the end of the 18th century it was estimated that two thousand Jews worked as old-cloth traders. Todd M. Endelman, *The Jews of Georgian England*, (Ann Arbor: University of Michigan Press, 1999) pp. 171, 182-183. On the dependency of rag merchants on the work of the poor see: D. Coleman, *The British Paper Industry,* pp. 166-167.

[116] John N. Balston, *The Whatmans and Wove Paper: Its Invention and Development in the West,* (West Farleigh: Balston, 1998).

[117] J. Balston, *The Elder James Whatman*, p. 162.

[118] On the introduction of the Hollander technology: J. Balston, *The Elder James Whatman,* pp. 216-224.

[119] J. Balston, *The Elder James Whatman,* pp. 234-238.

already been turned into a paper mill from a fulling one in the past, however in 1736 they wanted to rebuild it. [120] After Harris' death in 1739, Whatman remained to lead the venture. Under his management Turkey Mill became the largest and most advanced site of paper manufacture in the country and his name gained international prominence for the innovative introduction, first attested to in 1757, of a mould of finely woven wire mesh that produced a smoother and more uniform sheet than the traditional tool.[121] The activity in the mill thus marked not just the achievement of a widely recognised quality but, above all, the transition of the manufacturing to an industrial scale.

As with Genoese merchants who had already profitably put in place a century before the technology of stampers, the pursuit of efficiency was key for competitiveness, and that accomplishment expressly required the design of the means of production around the process of papermaking itself. Harris and Whatman, indeed, instead of adapting the paper manufacture in old inefficient mills, first gained a full proficiency of the Hollander and then redesigned the mill around the process renewed by the adoption of the new engine. By the end of the century, with Whatman's son, Turkey Mill became "the most influential example of its kind" and several other significant improvements were developed there.[122] By 1794, it operated 5 vats, 24 presses and the most advanced features, such as double shutters in the drying lofts, like an extremely advanced manufacturing plant.[123] Turkey Mill's massive construction thus went on to represent the newest advancement, while playing the role of a leading entrepreneurial model. It is understandable how the successful venture of the Whatmans might have encouraged the entrepreneurial attempts of others, with the further advancement offered by the steam engine, first introduced in a paper mill near Hull in 1786.[124] It is in the light of those sort of grand ventures that we can undoubtedly place the episode of Matthias Koops. He must have looked at previous examples such as that of James Whatman when embarking on his own ambitious plan for the first industrial production of paper without rags.

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[120] Theresa F. Harris, Michael Fuller and Maureen Green, "Papermaking and the Whatmans" in Theresa Harris, Scott Wilcox (ed. by) *Papermaking and the Art of Watercolour in Eighteenth Century Britain: Paul Sandby and the Whatman Paper Mill* (New Haven, London: Yale University Press, 2006). pp. 61-119, p. 78.
[121] J. Balston, *The Whatmans and Wove Paper,* pp. 127-147.
[122] On the series of innovations developed in the Turkey Mill, from the Wove paper, to the watermark ruling, and the new "antiquarian format" see: Theresa F. Harris, Michael Fuller and Maureen Green, "Papermaking and the Whatmans" in Theresa Harris, Scott Wilcox (ed. by) *Papermaking and the Art of Watercolour in Eighteenth Century Britain: Paul Sandby and the Whatman Paper Mill* (New Haven, London: Yale University Press, 2006). pp. 61-119, pp. 63, 77-87.
[123] T. Harris, M. Fuller and M. Green, "Papermaking and the Whatmans", pp. 95-97.
[124] R. Hills (ed. by) *Studies on the History of Papermaking in England,* p. 72.

5. The future within paper

5.1 Matthias Koops: redesigning the material of paper

The figure of Koops, in the view of paper historians, appears as an ambiguous one. According to Dard Hunter, writing in 1943, Koops was an elusive but revolutionary figure.[125] More recently, historiography moderated that enthusiastic opinion and turned to a much more pragmatic viewpoint.[126] Archival records have been retrieved since then, and the portrait of an over-confident entrepreneur, who failed in his most ambitious project, has been traced instead.[127] We know now that the enterprise of Koops, based on the activity of two paper mills, was an important one. Both mills run by Koops were located in the proximity of central London, being Neckinger Mill in Bermondsey and Millbank not far from Vauxhall. Together they composed the largest enterprise in the British manufacture of paper at the time.[128] The plan required the guidance of personalities of contemporary engineering and cutting-edge technologies, such as "the most complete and substantial" steam engine to date, all of which necessitated a remarkable investment of capital. "Nothing was stinted" it has been stated, yet the plan ended in 1802 with clamorous sales due to insolvency, only a few years after the start of the venture and the launch, in 1800, of his showy book printed on paper made "*soley from straw*".[129]

Matthias Koops was not a professional papermaker. Born in Pomerania, he was mentioned as a merchant when naturalised as British in 1790.[130] As a businessman he certainly was a cultured one driven by wide-ranging interests. He had just written a small treatise on France's commercial benefits in the navigation of European waterways and attempted a business in the

[125] D. Hunter, *Papermaking, The History and Technique of an Ancient Craft*, 1st edn. 1943. (Dover: New York, 1979), p. 332.
[126] John Bidwell, "The Industrialization of Paper Trade", in *The Cambridge History of Book in Britain, 1695-1830*. ed by Michael Suarez and Michael Turner, vol. V, (Cambridge, Cambridge University Press, 2009), pp. 200-217, pp. 205-6.
[127] Richard Goulden, "The Shadow Limn'd: Matthias Koops", IPH information, 1989, no.2. pp. 75-85.
[128] Alan Crocker and Robin Clarke, "Matthias Koops at Neckinger Mill, Bermondsey", *The Quarterly: The Journal of the British Association of Paper Historians*, no.39, July 2001. pp. 15-22, p. 17.
[129] Arthur Chick "Paper from straw: Matthias Koops in London", *Antiquarian Book Monthly Review*, Vol.12, issue 132, April, 1985, pp. 140-145, p.143 and Alan Crocker and Stephen Humphrey, "The Papermaker and the Prophetess: Elias Carpenter of Neckinger Mill, Bermondsey, Supporter of Joanna Southcott", *Surrey Archaeological Collections*, 89, 2002, pp. 119-135, pp. 129–31, 121-125.
[130] Alan Crocker and Robin Clarke, "Matthias Koops at Neckinger Mill in Bermondsey", p. 16.

insurance sector, going soon bankrupt for the first time.[131] His venture in the paper trade has been indicated as beginning only in 1795, when he apparently started experimenting on alternative materials to rags for papermaking. For that purpose, he began a collaboration with two experts in the field. The first one of them was the papermaker Elias Carpenter, who in the same year had just patented a method for bleaching paper and sizing it without drying. The other one was the chemist Hector Campbell, who was granted a patent in 1792 for the bleaching of rags using gaseous chlorine.[132] The partnership with the two specialists had to be intense and the registration of three patents under Koops' name testify to that exchange. Dated between April 1800 and February 1801, those patents related to experiments on papermaking and, it has been noticed, they had to require some understanding of applied chemistry, which might not have been possible without the specific knowledge of Carpenter and Campbell.[133]

Unfortunately, notwithstanding the interest of paper historians in the case, no scientific analysis has been carried out on the varieties of paper that had been produced in Koops' mills. However, it is now widely accepted that the self-celebratory statement about that paper, which he proclaimed to be made simply from straw, scrap prints, and wood, should be reconsidered. From a recent inspection on the many variations among 86 copies of the second edition of his work, it has been concluded that the stock of straw and wood paper used was evidently "not enough for the proposed print run".[134] That scarcity, it has been suggested, might have been the result of some technical problems. In particular, the poor quality of his experimental paper had possibly determined a larger waste than normal during the process of printing, possibly due to the considerable number of sheets that had to be discarded. Moreover, it has been hinted that some rags might, reasonably, have been added to improve the strength and quality of that paper.[135] Finally, the same analysis also observed that the intense yellow tint of those pages might have possibly been obtained deliberately, which would mean that Koops had craftily

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[131] Matthias Koops, *A Development of the Views and Designs of the French Nation, and the advantages which will derive to them, if they should be able ... to secure to themselves the free navigation of the rivers Rhine, Maese, and Scheldt*, etc., (London, 1796).

[132] A. Crocker and S. Humphrey, "The papermaker and the Prophetess", p. 122.

[133] April 1800: "extracting printing and writing ink from printed and written paper, and converting the paper from which the ink is extracted into pulp, and making thereof paper fit for writing, printing, and other purposes.", *Repertory of Arts, manufactures and Agriculture*, vol XIV, (patent dated April 28, 1800). August 1800: "manufacturing paper from straw, hay, thistles, waste and refuse of hemp and flax, and different kinds of wood and bark, fit for printing, and other useful purposes" xxxvi Specification of the patent granted to Mr Matthias Koops, of queen street, Ranelagh, in the County of Middlesex, Gentleman; for his invention of *Repertory of Arts, manufactures, and Agriculture*. n. IV, second series, Sept. 1, 1802, pp. 241-246 (patent dated February 17, 1801). Considering his background, it has been noted, it is unlikely that he was solely responsible for those patents which "involved a thorough understanding of applied chemistry". Alan Crocker and Stephen Humphrey, "The Papermaker and the Prophetess".

[134] Alan Crocker, "A Study of Matthias Koops' Book on the History of Papermaking" in in Rosella Graziaplena and Mark Livesey (eds.), *Paper as a Medium of Cultural Heritage, Archaeology and Conservation*, (Roma: Istituto per la Patologia del Libro, 2004) pp. 73-84, pp. 79-82.

[135] Ibidem pp. 82, 84.

pursued the chromatic expectation of straw. All these considerations are certainly relevant when revealing the actual difficulty of Koops' project, but they also invite us to reflect more on the reasons behind his plan. Assuming the deliberate work of dissimulation that he may have wanted to carry out, his ploy had strong targets. By pretentiously proclaiming of being able to make paper from straw, he was clearly taking advantage of his patents. Nonetheless, he also conceivably created some expectations by anticipating a result, while striving to be genuinely able to make a considerable amount of good quality paper without rags very soon.[136] In this way, he was probably drawing on the necessary financial resources for his ambitious project. Nonetheless, although reasonable, these points do not give a complete overview of Koops' vision, which led him to plunge into his venture with noteworthy confidence. More importantly, from an historical point of view, it would be wrong to assess the relevance of his case only on the basis of the failure of his business. The evidence of his struggle of making a paper suitable for printing from alternative raw materials makes his refined volume, printed on those yellow straw pages, a remarkably representative instance of Koops' vision. Those pages especially embody the foresight of paper as the future key material, which actually became.

5.2 Paper between two ages: the vision of Matthias Koops

As expected for a singular episode like that of Koops, several studies have explored the circumstances through the relevant documents. However, it is remarkable how little interest has been raised about the vision that Koops fostered over his experimental paper, which emerges primarily from the content of the two editions of his book. [137] It is in the light of such a vision that his contribution to the history of paper's design is at least well-deserved. These elements are worth being considered here. The book clearly indicates that he pursued his plan primarily by breaking the conventional use of white paper for formal publications. As we can infer from his writing, indeed, he was directly inviting readers to abstain from prejudices and shift their perception of paper to a new perspective. He thus openly deplored the "prejudices (…) cherished against the new discoveries" and blamed them regarding the "pleasing" aspect and "natural colour" of his straw paper, which he defined as "grateful to the eye" and able to take impressions better than the one imported from France.[138] By appealing to the concepts of

[136] Repeatedly in his books Koops mentions the incoming large production from his invention as happening in a matter of weeks. ed. 1800, p. 86, ed. 1801, pp. 251, 260.
[137] An impressive analysis of his books has been carried out on 86 copies of the two editions of his book found in libraries of Europe and North America. The study has revealed up to the smallest detail and variations of Koops' editorial endeavour. Alan Crocker, "A Study of Matthias Koops' Book on the History of Papermaking" pp. 73-85.
[138] M. Koops, *Historical Account of the Substances* (ed. 1801), p. 253.

innovation and performance, Koops directly addressed the general discernment of paper as a possible drawback to his success and reinforced such values with the ideal of national primacy. As far as we can read from his volumes, much of Koops' ambitious plan was projected into the future, alike the material he pursued to produce. Encouraged by the most recent commercial application of japanning varnish to papier-mâché by the craftsman Henry Clay in Birmingham, Koops contemplated any potential development of his paper made from diverse fibres. He imagined it to be well beyond the simple support for printing. To him, paper was rather an all-round material of fibres whose uses, from "covering for buildings" to "carriages" and "household furniture", might have been greatly extended by pasting it in layers or mixing it with other substances. He thus envisioned a new ground-breaking material: strong, light, fine-looking, which could have been made incorruptible, flexible to ply, potentially incombustible and even more durable than wood itself.[139]

While ambitiously projected toward those opportunities, Koops' plan was well-grounded in the past too. His vision, indeed, was sensibly fostered on some evidences from the ancient and recent past, which composed a background of knowledge on which he conceived his whole venture. He certainly had to be a keen reader, since his information in the field of paper history was truly impressive. After recognising the key role that paper had in civilization and in the development of "art and science", Koops recalled the use of alternative raw materials for making writing supports based on a very long tradition of literature that started with Pliny and to which Koops amply and discernibly referred while considering the most pragmatic points of view.[140] Since the book was primarily aimed at advertising his alternative paper, as has been stated, such a proof of erudition might have sought to dignify his product in order to drive resources to his venture. [141] Nonetheless, Koops' historical knowledge also provided a coherent motivation for the experimentation he was undertaking: since the aspect and substance of paper considerably differed through the centuries and among various cultures, they were now overly due to change again. He thus endorsed his venture with a sense of historical inexorability. Correspondingly, his confidence was sustained on the adamant faith in the innovative scope of science. His idea was indeed supported through the examples of some naturalists, who had

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[139] *"It may probably be ultimately proved, that paper thus prepared, will be a lighter, neater and more durable covering for buildings of all kinds and it is equally true that the ingredients, with which the cement may be composed, will render this substance not only incombustible but more durable than slates, tiles (…) and wood in its natural state, and incorruptible by insects. Who can say that coach-makers, chair-makers, and cabinet-makers, will not make use of it for carriages, chairs, and elegant household furniture, and reflect that that substance possessing such superior properties ought to be preferred, having flexibility, hardness and capability of being worked with infinite neatness and lustre than wood, which is so much affected by the air and weather".* M. Koops, *Historical Account of the Substances* (ed. 1801), p. 261-263

[140] M. Koops, *Historical Account of the Substances* (ed. 1800), pp. 9, 23.

[141] Alan Crocker, A study of Matthias Koops, p. 83.

experienced in person how paper was the outcome of processes occurring in nature.[142] To them Koops granted his own respect, naming them as his sources. This was indeed the first time that somebody was determined, on such a strong convergence of reasons, to pursue an innovative redesign of paper on an industrial scale with extraordinary devices and capital.

To conclude, Koops was clearly pushing in all possible directions. He was ensuring the indispensable assets for his venture while promoting his results, prospecting for the future ones and conditioning the current perception. On a more practical ground, with the involvement of a papermaker and a chemist, he was relying on the respective proficiencies of their craftsmanship and recently applied chemistry. More importantly, he was supporting his envisioned future of paper on the precious knowledge of contemporary naturalists and even some botanists, who had already attempted his same route in the past, although on an experimental scale. The success had to look ineluctable and at hand in Koops' eyes, nonetheless we know now that, in practice, such a target was not easy. Several decades passed, indeed, before it was actually possible to revise the whole process in order to adopt cellulose from wood as an effective source of fibres for making paper, finally freeing paper's manufacture from its long dependence on rags.[143]

Koops' vision, which emerges from his own words, was undoubtedly comprehensive and, in order to appreciate its real meaning, it would be reasonable to consider the diverse aspects on which such an extraordinary conception of paper was grounded. That target, however, would require a broader perspective than the one outlined by Koops in his book. How had the necessary knowledge developed in order to conceive of paper as an innovative material? How did the use of paper and the practices on it change, determining that enlightened vision, and how had the perception of that material, in turn, changed through time? Finally, what was the actual role of science, implied by Koops' mention of botanists' and naturalists' names? These questions will be addressed in the following chapters.

Conclusion

This chapter provided a sketchy summary of the events that can be outlined from the narrative of the most conventional studies of paper history. Despite its conciseness some

[142] M. Koops, *Historical Account of the Substances* (ed. 1801), p. 233.
[143] The way to that discovery is today the theme of a research project carried out by Francesca Kubicki at Kew. For a recent study on the earliest development of paper from the cellulose of wood see: Peter Burger, *Charles Fenerty and his Paper Invention*, (Toronto: PB Publishing, 2007).

important elements can be gathered from the overview offered by those studies. From the traits of the manufacturers in Genoa and England, notwithstanding the singularity of each case, we can clearly trace a progressive development. In Genoa, the local elite of merchants invested profitably in the long-established manufacture of paper, which became a core business for that area. As a consequence, while the production started to grow substantially, the craft progressively developed into the earliest form of a capitalist production. As a manufacturer in which the means of production were profitably designed in order to maximise production, the example of Genoa was thus destined to establish a model for the future industry of paper. On the other hand, we have seen how England, a country dependant on the importation of that good, progressively became more determined to establish its own domestic production. The connections and exchanges with the manufacturers abroad were crucial to that achievement and, despite an endemic shortage of rags, the know-how grew with distinctive characteristics especially concerning a more flexible use of fibres and a vital receptiveness to innovation. It was on those foundations that the English manufacture of paper not only reached a production level suitable to satisfy the increasing domestic demand, but also reshaped itself, extending its scope to an industrial scale. Seen in that continuity, therefore, the different conditions in which papermaking took its forms in Genoa and England triggered some decisive dynamics within the transnational development of its manufacture: an evolution that allowed not only the conception of the manufacture of paper itself as an efficient industry, but also to envision paper as an incoming mass commodity.

The studies of paper history illustrate many important aspects concerning how such a good was produced, along with the technology it involved with respect to its market, while considering the corollary topic of social and economic repercussions. More importantly for our case, those studies provide the basis on which historians have recently started to acknowledge that, besides national narratives, the history of paper can be constructively explored as a transnational phenomenon. By virtue of such aspects, we can develop our argument in the next chapters by focusing further on England and Italy. Yet, despite their opening towards the transnational perspective, the studies of the history of paper present a generic limitation in scope. Being based on written documents and endorsed by archival records, their narrative primarily presents an historical narrative of paper as the development of a production, in which paper emerges mostly as a mere commodity. Nonetheless, some of the cases considered in this chapter, when explored in some detail, reveal that the history of paper, in reality, was a more complex phenomenon and paper was more than the result of a manufacturing process or the article of a trade.

From Matthias Koops' own writings, beyond the evidence explored by the literature, we have seen how his personal venture was actively imbued with a wealth of cultured and scientific knowledge about paper to which he clearly had easy access. That body of knowledge conditioned his enlightened endeavour and he genuinely looked at it with confidence in order to achieve his manufacturing purpose. However, far from being a marginal aspect of paper history, that same body of knowledge was the result of a long-lasting engagement of European culture with the material of paper and, as such, it deserves to be explored in detail.

Whereas the knowledge and relative perception of paper had a role in the history of such a material, we cannot exclude from the present study the utilitarian resourcefulness of paper as an influential medium and equipment. The way Domenico Peri embraced his own argument, when writing his manual about the practice of accountancy joined with the investment in the business of paper, is revealing. As we have seen, in Peri's conception, paper was the manufactured good the merchants had built their fortune on. Nonetheless, it was also the essential instrument through which those same tradesmen kept accounts of their business, and possibly even the medium they relied on to conceive its rationalisation in the first place.

The knowledge about paper and the practices concerning the use of paper are what we can define as the constitutive aspects of the engagement with a material that, in the 17th and 18th centuries, was also becoming increasingly pervasive. Undeniably, those are not external elements of a narrative aspiring to illustrate a more comprehensive perspective of the history of paper. Indeed, while paper was produced and traded, it was simultaneously and increasingly handled by many people in diverse contexts and in different resourceful ways. Moreover, within the time frame considered in the present research, paper also started to be significantly scrutinised and even actively experienced by some naturalists. Those examples of material engagement, despite not being directly related to its manufacture, became influential and contributed to the development that eventually transformed paper into the material we know today.

In conclusion, from this analysis I argue that the history of paper could not be limited to a narrative that describes the economic and manufactural development of a good. As Koop's case suggested, paper by the 18th century was in the process of being redesigned at its core. By that time paper was not only a commodity anymore and not even just a tool of knowledge, as Koops' book exquisitely reminds us, but rather it had become an object of knowledge in itself, both as a matter of fibres and as a technical process that even occurred in nature and Koops' venture was grounded on such a basis. Therefore, tracing a comprehensive history of paper should ideally embrace paper in all its aspects, not just as a good but as a technology and as a matter,

as well as the result of a process. This is, in other words, the ambition of the present work and we are going to undertake that task in the following chapters, by considering in detail how paper was used, seen and made.

Chapter II

Using paper: From the resourceful material to the technology of modern science

Introduction

In the previous chapter, we have discussed the conceptions of the Genoese businessman Giovanni Domenico Peri and a statement in his treatise on accountancy leave us with a pending matter concerning paper. His assertion that "everything is easily rendered and brought to accomplishment by means of paper" might appear as vague literary rhetoric, if we fail to consider its actual meaning in the more comprehensive context of paper's use as a resourceful material. The present chapter will discuss the use of paper, primarily in Italy, from the late 16th to the mid of 17th centuries by focusing on how, from being a versatile tool, it was embraced as a proper technology. In particular, the chapter will address paper's transition from a flexible material and resourceful medium in the hands of users and artisans, to its adoption as an invaluable technology of science. I will argue that the scientific community gradually embraced the medium of paper in its material form not only for developing textual contents but also for visual ones. The result of such a transition, which started in 16th century Italy, was far-reaching, as we are going to see. Paper endowed scholars with an authoritative and resourceful means for visualisation on which the new science laid its foundation and, more importantly for the outcome of the present research, it gradually steered science toward a new interest in matter.

The chapter develops in four main parts. The first preliminary part provides an overview on the affordability of paper as a good in relation to the proliferation of practices among common users, who valued the material resourcefulness of paper and paper artefacts. On such a basis, I analyse in particular how paper was used among the elite of scholars, which is the core theme of the whole chapter. The second part presents two sections. The first one addresses how paper increasingly established the material environment of the learned with the consequent problem of "information overload", while the second one considers the growing

body of literature that, referring to the terms “paper tools” and “paper technology”, is currently exploring the instrumental use of paper for the elaboration of textual content. The third part of the chapter is more articulated as it presents my personal contribution to that debate. In there I suggest considering paper as an instrumental technology, not just with regard to textual contents but also to visual ones. My own argument is developed in a brief introduction and the four main sections, exploring primarily the case of Italian botanists from the late 16th to the early 17th centuries as an influential one within the European context. In the introduction I define a propositional criterion for my analysis since any artefacts, whether prints, drawings, maps or herbaria, are to be considered significant in exploring the technology of paper from the material standpoint. On such a premise, in the first section I address the theorisation of Hans-Jörg Rheinberger on the visualisation procedures through epistemic objects in modern science. Although primarily based on contemporaneity, his theoretical framework allows me to reflect on the critical role of paper within the foundational methodology of modern scientists. The second section focuses on the techniques of herbaria and nature prints as the most influential procedures of visualisation that originated from the practice of apothecarists. I argue that, once these techniques were adopted by Italian botanists and the scientific community of Europe, they led scholars to gradually embrace representation on paper as a reliable medium of knowledge. The third section explores in more detail the actual overlooked impact of nature prints and herbaria with regard to the active use of the material medium those techniques imply. By considering the direct engagement with the botanical specimens through the action of paper, I argue that nature prints and herbaria prompted a deeper meditation on organic matter, nature, and its phenomenology. Thus, while taking impressions of leaves led to Fabio Colonna’s theorisation on the formation of fossils, desiccating herbs was raising a general awareness of the transformation of organic matter. In turn, both those techniques brought a new insight into the material of paper. In the fourth section I consider how such an active role for paper as a visualisation technology was explored by the first members of the Accademia dei Lincei: Federico Cesi and especially Cassiano dal Pozzo. As I analyse Cassiano’s drawings from his “Paper Museum”, I consider how paper was embraced by the Linceans as a thorough technology to visualise nature. The last part of the chapter develops in two sections and aims at contextualising my analysis. In the first section I review my investigation in the light of Malafouris’ material engagement theory. On such a theoretical ground, the shift from embracing paper as a textual instrument to a visual one, in science, can be read as a cognitive shift that deeply entails an experiential understanding of paper’s properties. All of this allowed paper to be consciously embraced as a proper technology in the hands of scientists. The second

section, at the end of the chapter, intends to clarify a more general context with regard to the material engagement of paper. That final section, therefore, widens the scope of my research by concisely indicating that the epistemic use of paper among scientists essentially originated from the techniques developed by artisans and that the medium of paper itself should be considered as a crucial technology for knowing and making.

1. An affordable and resourceful good

By the late 16th century, paper was a widespread good in Europe. Its demand was growing rapidly, sustained by an expanding supply, which in turn was made possible by both increased productivity and the rapid settlement of new manufacturers as seen in the previous chapter. Paper thus entered people's lives in a range of ways and forms. The best quality paper marketed for writing, although never cheap, represented a reasonably affordable choice, especially if compared to parchment, whose average cost has been estimated to be from four to eight times higher.[144] That ratio, however, was constantly diverging. The trend for paper's price, indeed, and without considering normal fluctuations, was in general a decreasing one.[145] Unlike in Italy, where paper had started to supplant parchment since the Middle Ages, the use of animal skin in England lasted for a longer time and still, in the 17th century, was a favoured writing support for deeds, liturgical manuscripts and official documents. Nonetheless, such usage was destined to also change in England, as paper was gradually introduced even for formal purposes.[146] A most significant distance between paper and parchment had already emerged with the ascent of the printing press, which clearly better conformed to paper as its optimal medium and for which, it has been reasonably suggested, paper may have even paved the way.[147]

Besides those facts, a more comprehensive overview of paper's value needs to be addressed. It might be useful to anticipate that such a value could not ever relate to our contemporary standards. When compared to the extreme affordability of today's paper, it may appear to have been an extremely pricey good, but elements suggest that, overall, even the most valued writing paper was not out of reach across the social classes. Gathering information on the real monetary value of paper from the sources is not easy. Its market price fluctuated

[144] Carla Bozzolo, Ezio Ornato, *Pour Une Histoire du Livre Manuscrit*, (Paris: Éditions du Centre national de la recherche scientifique, 1980) pp. 227-228.
[145] Rudolf Hirsch, *Printing, selling and reading 1450-1550*, (Wiesbaden: Harrassowitz, 1974), pp. 34-36.
[146] R.J. Lyall, "Materials: the paper revolution" in Jeremy Griffiths and Derek Pearsall (eds.), *Book Production and Publishing in Britain, 1375-1475* (Cambridge: Cambridge University Press, 1989) pp. 11-29, pp. 12-14.
[147] R.J. Lyall, "Materials: the paper revolution" p. 26.

according to a combination of different variables such as the volatile costs of raw materials, local circumstances and specific times. Therefore, the many mentions of prices reported by documents and literature only represent partial views of the broader picture. More importantly, records often lack from correspondence with the contemporary local costs of living. The literature addressing the production of printed books often indicates paper as the highest cost for printers. Reportedly, indeed, paper amounted to around half of the entire cost of a book.[148] That statement, however, needs to be contextualised. An important Italian study that compared the price of paper traded in Bologna in the late Middle Ages against the costs of the raw materials and manufacturing, revealed that paper was not particularly expensive. Paper's final cost was only 15% higher than that of rags.[149] In my previous research, indeed, I was able to attest from the statutes in Bologna, which set the prices of goods as well as labourers' wages, that the daily salary of a ploughman in the second half of the 15th century corresponded to 21 sheets of large-format writing paper and as many as 150 small low-quality ones.[150] With the expansion of the production scale, the competition of markets, and the drive toward lower prices, which Genoa especially pursued, the cost of paper was inevitably destined to contract during the early modern period. Over the long term, indeed, a downward trend in price was still indicated in the 18th century.[151] Despite the different conditions, the English case wasn't too dissimilar from the Italian context. Coleman, by merging historiographical data, observed a significant drop of 40% in paper's price during the 15th century, as against a rise of between 20% and 50% in that of parchment.[152] Nonetheless, he also considered how 17th century internal politics had later played a role in deliberately raising the retail cost by levying a duty on imports so as to encourage domestic production.[153] For that century, Coleman's study indicated a cost per single quire, consisting of 25 sheets, of 4 to 5 pence and in the 18th century between 10 to 30 shillings per ream of 500 sheets, equivalent to 6 to 18 pence per quire.[154] These bare data, however, has little meaning without a comparison with real-life costs. Heather Wolfe has recently compared Coleman's information with labourers' wages, inferring that an average worker, who earned between 6 and 12 pence per day, could purchase up to 75 sheets of writing

[148] Jean-Francois Gilmont, "Il libro e la lettura: dal rotolo all'ipertesto" in Giancarlo Petrella (ed. by), *Dalla pergamena al monitor*, (Brescia: La Scuola, 2004) pp. 14-32, p. 23, Giovanni Bonifati, *Dal libro manoscritto al libro stampato: Sistemi di mercato a Bologna e a Firenze agli albori del capitalismo*, (Torino: Rosenberg & Sellier, 2008) pp. 128-132.
[149] E. Ornato, *La carta occidentale*, vol. I, pp. 178, 179.
[150] A.S.Bo., Statuti del Governo, Vol. XIX, (fol. 453v). See transcription in: Maria Alessandra Chessa, *Between the Ordinary and the Extraordinary. Experimentations and practices on paper in Renaissance Italy,* Ma Dissertation, Royal College of Art, 2012. p. 24
[151] Marco Piccardi, "Mercato, consumi e prezzi della carta", in Simonetta Cavaciocchi (ed. by), *Produzione e commercio della carta e del libro*, (Firenze, Le Monnier, 1992), pp. 279-298, pp. 293-295
[152] D. Coleman, p. 7.
[153] D. Coleman, pp. 353-355
[154] Ibidem

paper with his own daily pay.[155] If we accept these figures, although approximate, we can conclude that in England also the cost of paper did not put it out of reach, even for normal workers, which clearly explains why paper was destined to be greeted as a successful and pervasive medium.

Besides the more expensive writing paper, the type destined for printing was not only commonly adopted for all sorts of books and publications, but was also familiar among the lower class, who widely experienced that quality in the form of popular goods such as devotional prints, playing cards, fans and ballads. Along with the printing paper, the lowest quality papers were also widespread. Those were generically indicated for wrapping, although their actual applications ranged from wrappers, book covers, and pasteboards to windowpanes, only in use in Italy, and included the wool pressing type, sometimes mentioned in 18th century England. It was especially from those lowest qualities of paper, indeed, that a significant range of varieties started to appear in the 18th century, designed for new specific purposes, such as blotting paper that we are going to consider in the last chapter. Much of that information on the qualities of paper in use, commonly reported by traditional literature, has been retrieved from the most conventional written sources. However, what the historiography of paper history has hardly addressed, because of the nature of the written sources it primarily relies upon, is the sphere of practices concerning the versatility of paper once it reached its users' hands. Practices, however, should not be considered as a secondary aspect within paper's history. These rather offer a favourable viewpoint to reflect on how the engagement of users with the material of paper finally led to its redesign from alternative sources. By taking artefacts and objects as a core source, the studies of material culture, since their rise, have inevitably started to explore the aspect of practices. Their methodological approach is now consequently contributing to extending our understanding of paper's actual meaning in the development of European culture. It is through those studies that we have started to appreciate the actual resourcefulness of paper as commonly experienced by different categories of users. That aspect especially, emerged from the innumerable cases revealing paper's wide applications, and often its reuse, from the devotional and ornamental purposes to the practical function of bookbinding or the simplest utilitarian one of lining boxes.[156] Many of these cases testify that even the most humble

[155] Heather Wolfe, *Was Early Modern Writing Paper Expensive?* 13 February 2018. https://collation.folger.edu/2018/02/writing-paper-expensive/ Accessed: January 2019.

[156] The cases of uses and reuse of prints explored in the literature are innumerable. Suzanne Karr Schmidt, *Altered and adorned: Using Renaissance prints in daily life*, (London, New Heaven: Yale University Press, 2011). Juliet Fleming, "Damask Papers", in Andy Kesson and Emma Smith (eds.), *The Elizabethan Top Ten: Defining Print Popularity in Early Modern England,* (Farnham: Ashgate, 2013) pp. 179-191. Martha Moffitt Peacock, "Paper as Power: Carving a Niche for the female artist in the Work of Joanna Koerten" in Ann-Sophie Lehmann, Frits Scholten, H. Perry Chapman (eds), *Meaning in Materials, 1400-1800*, (Leiden: Brill, 2014) pp. 238-264. Elizabeth Miller, "Prints", in *At Home in Renaissance Italy*, ed. by Marta Ajmar, Flora Dennis, (London: V&A Publications, 2006), pp. 322-331. For the case of

user could see a print or a playing card as a potentially adaptable piece of paper that could be altered in many ways by pasting it onto surfaces or turning it into a wrapper, as well as cutting or re-pulping it, thus flipping its function well beyond the initially purported one.[157] To adopt a term from the field of psychology of perception, we may say that users actively explored and constantly witnessed paper's many "affordances".[158] By easily responding to the necessities, arrangements and possibilities envisioned by users, paper was instinctively embraced as a multipurpose tool. Those cases clearly demonstrate that paper was a resourceful commodity in its own way. It is under that aspect of dynamic reciprocity between the material's receptiveness and the users' absorption that we are going to consider how paper, once it reached the world of the learned, came to be embraced as a proper technology.

2. The scientists' world of paper

A few years ago, some studies on book production in Britain unexpectedly noticed that paper in the late Middle Ages had been established as a favoured medium for academic and scientific purposes compared to parchment.[159] More recently the codicologist Kwakkel referred to those studies to support his argument on how the medium of paper by then had started to better conform to the necessities of an emergent new kind of reader.[160] By the early modern period paper was indeed the prevalent medium of science and the amount of paper involved in the daily practice of the learned was gradually becoming substantial. Books, manuscripts, notes, letters, casebooks and practice journals handled by scholars had necessarily to be many.[161] A

Jacopo Rubieri see: Evelina Borea, Fiora Bellini, *Xilografie Italiane del Quattrocento da Ravenna e da altri luoghi,* (Ravenna: Longo editore, 1987)

[157] The reuses of playing cards for making holy effigies in early modern Italy and England represents a stimulating analogy. Richard L. Williams, "Contesting the Everyday: The Cultural Biography of a Subversive Playing Card", in Tara Hamling and Catherine Richardson (eds.), *Everyday Objects: Medieval and Early Modern Material Culture and its Meanings*, (Farnham: Ashgate, 2010) pp. 241-256. For the Christ of Playing cards see: Maria ALessandra Chessa, "The Substance of Divine Grace: Ex-Votos and the Material of Paper in Early Modern Italy" in Suzanna Ivanič, Mary Laven, Andrew Morrall (eds.) *Religious materiality in the early modern world*, (Amsterdam: Amsterdam University Press, 2019) pp. 51-66.

[158] James Gibson, *The Ecological Approach to Visual Perception*, (Boston: Houghton Mifflin, 1979).

[159] Linda Ehrsam Voigts "Scientific and medical books" in Jeremy Griffiths and Derek Pearsall (eds.) *Book production and publishing in Britain 1375-1475*, (Cambridge: Cambridge University Press, 1989) pp. 345-402 and Linne Ruth Mooney, "Manuscript Evidence for the Use of Utilitarian Writings in Late Medieval England" in Richard Firth Green and Linne R. Mooney (eds.) *Interstices. Studies in the Middle English and Anglo-Latin Texts,* (Toronto: University of Toronto Press, 2004) pp. 184-202.

[160] Erik Kwakkel, "A New Type of Book for a New Type of Reader: The Emergence of Paper in Vernacular Book Production" in Jane Roberts and Pamela Robinson (eds.) *The History of the Book in the West: 400-1455*, (London: Ashgate, 2010), pp. 409-438.

[161] On the specific case of letters see: Anthony Grafton, "A Sketch Map of a Lost Continent: The Republic of Letters", *Republic of Letters: A Journal for the Study of Knowledge, Politics, and the Arts*, vol. 1, no. 1 (May 1, 2009) pp.1-18. https://arcade.stanford.edu/rofl/sketch-map-lost-continent-republic-letters. Accessed: 14 March 2018.

rapid overview of what concerned only the possession of books would give us a glimpse into that busy world of paper: one in which paper entered primarily as the medium for accessing the contents but, as we are going to see, in practice regularly turned out to be a more complex piece of equipment than a passive support for knowledge.

By the end of the 15th century, thanks especially to the ascent of the printing press, the number of books in the hands of scholars all over Europe was becoming remarkable. We know that the largest private collection of books in 16th century Italy was that of the humanist Gian Vincenzo Pinelli (1535-1601), accounting for a significant total of 9000 printed volumes plus hundreds of manuscripts.[162] Pinelli was not only an eager collector, who dedicated his entire life to gathering books for the sake of it, but also went as far as collecting books about books: manuscripts containing lists of books owned by Italian and European personalities and scholars of the time.[163] Although not on the same scale, but still substantial, was the possession of the Bolognese naturalist Ulisse Aldrovandi (1522-1605). The inventory of his own books is enumerated as 3900 volumes, a few of which were manuscripts and the rest printed works.[164] These numbers are remarkable when compared to some collections of certain 18th century scholars such as Linnaeus (1707-1778), whose private library numbered approximately 1600 titles.[165] However other scholars' possessions also demonstrated how books continued to represent a fundamental resource as crucial objects of knowledge. For example, at the end of the 18th century the personal library of British naturalist and botanist Sir Joseph Banks (1743-1820) accounted for as many as 14,000 books.[166]

Considering these figures and the consequent amount of information scholars were constantly in contact with, the expression "information overload" would now be commonly used to define that situation.[167] The historiography mentioned an early awareness expressed in 1545 by the Swiss botanist Conrad Gessner (1516-1565) about the "confusing and harmful abundance of books" in the incipit of his *Bibliotheca Universalis.*[168] Gessner understandably aspired to create some order among books by listing at least those printed in Latin, Greek and

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[162] Angela Nuovo, "Gian Vincenzo Pinelli's collection of catalogues of private libraries in sixteenth century Europe", *Gutenberg-Jahrbuch,* 2007, p. 129-144, p. 131.
[163] Ibidem, p.133
[164] Davide Lines, "La biblioteca di Ulisse Aldrovandi in Palazzo Pubblico: Un inventario seicentesco" in Renzo Ragghianti and Alessandro Savorelli (eds.) *Biblioteche filosofiche private. Strumenti e prospettive di ricerca*, (Pisa: Edizioni della Normale, 2014), pp. 133–152, p. 133.
[165] William Kelly, "Linnean Society Library", in Bernhard Fabian (ed), *Handbuch deutscher historischen Buchbestände. Großbritannien und Irland*. (Hildesheim: Olms-Weidmann, 2000) pp. 110-114, p. 111
[166] Rudiger Joppien and Neil Chambers, "The Scholarly library and collections of knowledge of Sir Joseph Banks" in: *Libraries within the Library*, ed. by G. Mandelbrote and B Taylor (London, The British Library, 2009), pp. 222-43, p. 238.
[167] Ann Blair, "Reading Strategies for Coping with Information Overload ca. 1550-1700", *Journal of the history of ideas*, 64, n.1, 2003, pp. 11-28.
[168] ibidem, p. 11.

Hebrew in his multiple-volume work. We could say that, paradoxically, the way to overcome such an overload, ease the access to the contents, and finally share that new knowledge, was achieved mostly by embracing even more paper, as the case of Gessner suggests. Rubrication, *tabulae* and the alphabetical indexing of headings were not new practices but dated back to the Middle Ages.[169] Although these aids became established as regular systems to facilitate the access to information within printed volumes, they only eased the retrieval of information within single books. Such dated strategies clearly were not a solution.

The main activity of scholars entailed the processing of knowledge from the pages of many different works. The practice of taking notes developed in several forms, from *marginalia* to loose sheets or notebooks.[170] The historiography has explored the details of the transition from the practices of note-taking, *florilegia* and collations to the birth of printed commonplace books.[171] Nonetheless, despite the large diffusion of various compendia by the 16th century, commentaries and the reference genre in general, by the late 17th century the abundance of information had to appear hard to process. The problem was not just due to an ever-growing number of publications, rather to the amount of new information they carried. It has been observed that the exponential surge of observations and discoveries, which constantly registered previously unknown specimens of animals and plants coming from the newly extended boundaries of the world, was overwhelming to scholars.[172]

What started to emerge in some of the most recent literature is the fact that paper was not used simply as a medium to access all that information. The main effort of scholars was indeed not just to collect and store data, but to work on it in order to study phenomena in their interconnections. Such a task was pursued not only by reconsidering previous knowledge in the light of their novel experience, but also by combining, incorporating and reframing it. Working on that knowledge, conveying it more effectively, combining ideas and incorporating new content, was facilitated through the physical manipulation of paper, as driven by its material versatility.

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[169] Ann Blair, *Too much to know: Managing Scholarly Information before the Modern Age,* (New Haven: Yale University Press, 2010). pp. 33-46.

[170] A good example of the practices of note-taking of academically trained physicians has been studied by Michael Stolberg, "Medical Note-Taking in the Sixteenth and Seventeenth Centuries", in Alberto Cevolini, (ed.by) *Forgetting Machines: Knowledge management Evolution in Early Modern Europe*, (Leiden: Brill, 2016), pp. 243-264.

[171] Ann Moss, *Printed Commonplace-Books and the Structuring of Renaissance Thought*, (Oxford: Clarendon Press, 1996).

[172] Brian Ogilvie "The Many Books of Nature: Renaissance Naturalists and Information Overload", *Journal of the History of Ideas*, vol. 64, n.1, 2003. pp. 29-40.

2.1 Harnessing the material texts

Expressions such as "paper tool", "paper machines" or "paper-based information technology" are today familiar concepts in a growing body of literature about the history of science.[173] Such studies hint that, in the historical practice of science, the paper support was involved in the strategies devised to process information, so that new content and knowledge were generated on it and through it. In some particular cases, indeed, the role of paper is recognised as a factor for the elaboration of knowledge, as we are going to see.

In the 16th century, Ulisse Aldrovandi, as studied by Fabian Kraemer, developed a personal strategy that actively engaged with the material support of paper, possibly derived from the experience he had acquired as a young bookkeeper.[174] Factoids, or pieces of information, when located in books and considered relevant to an argument, were transcribed and cut up in slips of paper containing a reference to the keyword of the subject, along with an indication of the source. In the second stage those paper slips were grouped according to the initial letter of their subject inside linen bags, one for each letter of the alphabet. As a last step, the slips temporarily kept in a mixed order were reconsidered and finally pasted with other related slips onto the pages of one of the 83 bound volumes of his *Pandechion Epistemonicon.* This was used as a major reference notebook of themes, organised in alphabetical order, in which slips were located at specific places. More importantly, as the traces of glue demonstrate, slips could still be removed in order to change position, thus finding a different, more relevant location within the volumes. Kramer's study also reveals that the system allowed for it to be operated conjointly with the help of some collaborators, who carried out part of Aldrovandi's work. The mobility of paper slips was at the core of that system. By fragmenting the linear consequentiality of a textual content, the pieces of paper allowed the basic information written on them to be freely recombined in any desired order. It is easy to appreciate how such a simple action could have played a significant role in the development of Aldrovandi's thoughts. Considering the amount of information that could be processed with such a rudimentary method, we can easily understand how the flexibility of Aldrovandi's slips was a crucial aspect of his methodology which, in such a preliminary phase, eased the envisioning of his arguments and led to his

[173] Ursula Klein, "Paper tool in experimental cultures", *Studies in History and Philosophy of Science*, 32, 2001, pp. 265-302. Boris Jardine, "Paper Tools", *Studies in History and Philosophy of Science*, vol. 64, 2017, pp. 53-63. Markus Krajewski, *Paper Machines. About Cards & Catalogs, 1548-1929*, (P. Krapp trans.) (Cambridge, MA: MIT Press, 2011). Arianna Borrelli, "Optical diagrams as "paper tools": Della Porta's analysis of biconvex lenses from *De defractione* to *De telescopio*", in Adriana Borrelli, Giora Hon, Yaakov Zik (eds.) *The Optics of Giambattista Della Porta (ca.1530-1615): A Reassessment*, (Switzerland: Springer, 2017) pp. 57-96.

[174] Fabian Kraemer, "Ulisse Aldrovandi's Pandechion Epistemonicon and the use of paper technology in Renaissance Natural History", *Early Science and Medicine.* Vol XIX no.5, 2014, pp. 398-423.

publications. Nonetheless, the practice of organizing information and notes in paper slips was not a peculiarity of the Italian naturalist's routine and scissors were indeed a familiar tool on literati's desks.[175] Cutting paper was a practice in constant development according to personal inclinations and needs. It should not therefore come as a surprise that such a practice was further developed in a more systematic way, as has been explored by other studies. Whereas Aldrovandi had pursued his personal method for handling information through its physical support, the German philologer Vincentius Placcius (1642-1699) conceived the mobility of paper slips as a proper system.[176] His "*De arte excerpendi*", as studied by Markus Krajewski, was a reference book on the different techniques for the selection and management of information on paper. The volume explained how to index the contents in books and organise that information in a systematic configuration, in which paper slips of consistent format, or *schedae*, were hung on thematic hooks within a purposely designed cabinet.[177] Such a singular piece of furniture, which he named *machina*, thus worked as a proper device to store, retrieve and combine information on paper.

The potentialities of holding, sharing, and shuffling information on loose paper slips within a network of people was envisioned in the middle of the 17th century by Robert Hooke (1635-1703), who suggested the adoption of a system of *schedules* for the Royal Society. The system, as Richard Yeo reports, consisted of a range of single "very fine pieces of paper" on which individual experiments and observations were briefly reported.[178] These were to be collected in a public book called a "repository" and pasted in it by using mouth glue in order for those slips to be moved around, compared and commented on to constitute an information network.

Finally, it has been possible to appreciate the advantages in the dynamic use of the uniform format of paper slips in the methodology adopted by Carl Linnaeus (1707-1778). The studies of Müller-Wille and Charmantier on the practice developed by the father of modern botany have revealed how the adoption of index cards played a crucial role in the development of his influential taxonomy.[179] Linnaeus' technique consisted of reporting information about each

[175] See especially the first chapter of: Adam Smyth, *Material Texts in Early Modern England*, (Cambridge, Cambridge University Press, 2018). pp. 17-54.
[176] "Ut chartae seu schedae perfilatae cohaereant, sive majores sint sive minores". Vincentius Placcius, *De Arte Excerpendi*, Hamburg, 1689, p. 68.
[177] Markus Krajewski, *Paper Machines. About Cards & Catalogs, 1548-1929*, (P. Krapp trans. (Cambridge, MA: MIT Press, 2011). pp. 17-21.
[178] Richard Yeo, "Between memory and Paperbooks: Baconianism and Natural History" *History of Science*, 45, n.1, 2007 pp. 1-46, pp.29-30. Yeo also studied the personal practice of Robert Boyle with regard to notes "loose and unpag'd sheets" as a method for easing thought and memory. R. Yeo, "Loose notes and Capacious Memory: Robert Boyle's Note-Taking and its Rationale", *Intellectual History Review,* 20, n.3, 2010, pp. 335-354.
[179] Isabelle Charmantier and Staffan Müller-Wille, "Carl Linnaeus's Botanical Paper Slips (1767-1773)", *Intellectual History Review,* 24, 2014, pp. 215-238. Staffan Müller-Wille, "Linnean Paper Tools" in Nicholas Jardine and Emma Spary, *Worlds of Natural Histories,* (Cambridge: Cambridge University Press, 2018). pp. 205-220.

plant on single standard format cards. Thus composed, the set of cards could be easily extended with the regular addition of new specimens as these emerged. More importantly, since cards were free from constriction and order, the set could be shuffled according to mutable criteria, which allowed for the comparing of diverse indexing configurations. Through regular practice, the system was fine-tuned and eventually turned out to be crucial in formulating a botanical classification system according to the sexual apparatus of plants: a criteria on which our current taxonomy of plants is based.

When considering the cases reported so far, as explored by that growing body of literature, we are inevitably brought to reflect on the resourcefulness of paper as a versatile medium that, being far more than a simple support, rather, was embraced as a proper tool. On such a principle, I believe, the instrumental use of paper and the consequence of its applications should be explored further.

3. The visual means: a material standpoint

The historiography has clearly demonstrated how, within the practice of the learned, the manageability and alterability of paper was embraced not just to convey textual contents, but also to reframe them, facilitating the processes of thought. In other words, paper was actively partaking in the development of knowledge through the contents it was carrying. Much less effort has been made over the instrumental use of paper with regard to its visual content and its far-reaching implications. This fact should not be surprising, since the historical understanding of visual contents is extremely problematic. Representations are much more evasive than texts. Knowing how a picture was meant to be perceived, who made it and why, requires a deeper contextual analysis. Moreover, a major problem that historiography met in understanding the role of paper concerns its intersection with the serial reproduction of images. Consequently, the instrumental use of visual content on paper has often been downplayed by the engrossing medium of print.[180] It may seem obvious, but it is necessary to remember that printing was only one modality within the possibilities offered by the material of paper. That premise allows us to make an important distinction concerning the nature of paper artefacts and a proposition for our analysis. Prints and drawings generally concerned different functions. The primary aim of prints was that of diffusing information to many readers, and that medium

[180] Susan Dackerman (ed. by), *Prints and the Pursuit of Knowledge in Early Modern Europe,* (New Haven: Yale University Press, 2011). Neil Rhodes and Jonathan Sawday (eds.), *Renaissance Computer: Knowledge Technology in the Age of Print,* (Taylor & Francis, 2002).

faced a number of questions relating to the practicalities of the editorial process. Consequently, prints provide a partial sense of how paper matters to our questions. Drawings, on the other hand, were more often related to the personal sphere of studies and, at times, they may testify more genuinely how images could be actively engaged with. In my attempt to explore how the material of paper was used, therefore, prints should not be considered more relevant than other visual means such as drawings or even herbaria, but not less important either. All of these artefacts were simply different with regard to their purpose and the way they were made, yet entirely significant in exploring the direct engagement of scholars with paper in order to investigate nature. On these premises, the perspective offered by an indistinct analysis of paper visual artefacts will help to see more clearly how that material, despite not being new, became to be embraced as an influential medium. In the following sections, therefore, I will present my contribution to the body of literature that has explored so far the instrumental use of paper among the scientists by considering how such material, in the 16th and 17th centuries, played a critical role within the procedures of visualization and the far-reaching consequences of such practices for the development of modern science.

3.1 The tool for visualisation at the origins of modern science

Paper gave form to a large category of artefacts that were regularly and systematically handled; aimed at conveying the visual content and concurrently stimulating new ideas. Such a comprehensive category of paper artefacts, which included not only simple illustrations of every kind but also maps, models and herbaria, could help us to articulate how paper came to be adopted as a major instrument for the practice of visualisation among scientists. Rather than being accessory activities, the procedures of making things visible were becoming a primary interest within the development of modern scientific practice.[181] According to Hans-Jörg Rheinberger, visualisation is defined as the "foundation" and the "foundational gesture" of modern sciences, which laid at its core the production of knowledge.[182] The theoretical framework that he provides on the procedures of visualisation is especially important as his research fathoms the practice of science in relation to artefacts, which he calls "epistemic

[181] The research of Barbara Stafford, although she mostly focused on the 18th century onwards, explored visualization as an epistemic means. See especially: Barbara Maria Stafford, *Body Criticism. Imagining the Unseen in Enlightenment Art and Medicine*, (Cambridge MA, The MIT Press, 1991) and Barbara Maria Stafford, *Echo Objects. The Cognitive Work of Images*, (Chicago: University of Chicago Press, 2007).

[182] Hans-Jörg Rheinberger, "Making Visible. Visualisation in the Sciences - and in Exhibitions?" in Susanne Lehmann-Brauns et al. (eds.), *The Exhibition as Product and Generator of Scholarship: Preprint 399*, (Max Planck Institute for the History of Science, 2010), pp. 9-23, p. 9.

objects".[183] Such an approach is revealed as crucial to our understanding of paper's wide-ranging instrumental role in the visualization procedures. That role will emerge especially once we have considered how the material of paper combined intrinsically with the practices of modern science in its embryonic phase. In his enlightening study, the science historian identifies three types of procedures indicated as: configuration, schematization and enhancement.[184] As he articulates these concepts, we gather that "configuration" concerns processes of dilatation and compression, aimed at bringing into the realm of the visible those phenomena that are not discernible because of limitations in space and time. His contemporaneous examples relate to the outcome of technologies such as ultracentrifugation or electron microscopy, which allow us to see what would have normally been undetectable.[185] We would not find it hard to include in such a group the vision of the spots on the sun that Galileo obtained through the telescope which, due to the intense brightness, required him to capture it on paper though an analogous procedure using the camera obscura. The magnified vision was directly sketched from its projection onto paper from which several copies were drawn and, as it has been observed, Galileo meaningfully referred to that type of picture as "printed by the sunlight" (fig. 2.1).[186] The vision, and its materialised projection on paper, were thus meant to be considered as integral parts of the same complex procedure of configuration. The category of configuration, as Rheinberger states, also encompasses forms of the "compression of structural data" such as maps. Into that group he includes geographical visualizations as well as those representations that make structural features accessible for mapping purposes.[187] Consequently, we can include the many types of anatomical tables aimed at offering a compressed mapping of the body's conformation, such as Vesalius' famous ones (fig. 2.2). Paper in the form of prints and drawings, therefore, articulated a large group of artefacts that conformed to the visualisation procedures of configuration.

More interestingly, paper also intrinsically conformed to the two other procedures of visualisation: "schematization" and "enhancement". The procedure of schematization, Rheinberger explains, especially aims at easing the exploration of the object under investigation and extends its knowledge by visualizing the processes and mechanisms of phenomena. This

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[183] Hans-Jörg Rheinberger, *An Epistemology of the Concrete. Twentieth-Century Histories of Life*, (Durham: Duke University Press, 2010), pp. 1-2.
[184] H. Rheinberger, "Making Visible. Visualisation in the Sciences", pp. 9-10.
[185] H. Rheinberger, "Making Visible. Visualisation in the Sciences" pp. 10-13
[186] The intricate process has been expounded by Mario Biagioli, who also compared the diameter of drawings and engravings, inferring that the first projections, once trapped on paper, allowed for the transfer of the trace for copies to circulate among Galileo's peers but also for transferring to the engraving plates to illustrate his publication. Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago: University of Chicago Press, 2006), pp. 189-195.
[187] H. Rheinberger, "Making Visible. Visualisation in the Sciences", p. 11

function is performed through artefacts that "resemble and make use of the forms" in which phenomena and their relative processes are experienced. The most typical case to illustrate such a procedure is represented by models. That category of epistemic objects, indeed, widely exemplifies the schematic mode of visualisation. As the aims of models is that of envisioning the operative features of the object or phenomenon under investigation, they could either take an abstract graphic form or a realistic three-dimensional one. The examples provided by Rheinberger for that category span from the graphic representation of molecular structures of RNA to the physical modelling of DNA first made out of cardboard and wire. An early modern example for that category is well represented by fugitive prints, such as the one included in Thomas Geminus' last edition of his "*Compendiosa totius anatomie delineatio*", which targeted a large public of readers.[188] A first-hand inspection of a well-preserved copy, indeed, allows us to appreciate the way flaps were conceived to reproduce the interconnected contiguity of organs (fig 2.3).[189] The flap representing the stomach is pasted from the last section of the oesophagus onto the back of the upper flap, thus showing how the food pipe, which appears in the first flap, is connected underneath the diaphragm with the upper part of the stomach. Analogously, the liver's flap is pasted onto the right side of the upper flap in order to represent its connection with the stomach. Although rudimentary, the flaps were not simply pictures to lift but were meant to illustrate the functional connections. That type of representation thus worked as a proper model that enabled the observer to explore on paper the structure of a body as if it were real through a hybrid form merging the plane figuration with the three-dimensional one.

The modality of visualisation that Rheinberger indicates as the one addressing most directly objects under investigation is the "enhancement". Such a procedure is harnessed directly from nature, for example through the injection of a contrast agent, as a means for making visible the venous conformation. The procedure of enhancement gave form to a large category of epistemic objects, technically defined as "preparations", that include microscope glass slides as well as preserved specimens in formalin solution. A very early type of dry preparation first adopted among the Italian botanists is the herbarium, aimed at extending the observation of plants into the cold season, as the early designations "desiccated garden" *hortus siccus* or

[188] That 1559 edition was meant to transmit anatomical knowledge to a large target of readers as the statement indicates "*to make common and familiere to al englyshe people"*. Thomas Geminus, *Compendiosa totius anatomie delineatio,* (London, 1559). Although Vesalius had contributed to provide authority to that form of visualisation as early as in 1543, for didactic purposes in his *Epitome*, Geminus' edition seems to indicate that in the 16th century that form of visualisation was still considered a borderline scientific tool. On Vesalius' fugitive prints see: Andrea Carlino, *Paper Bodies. A Catalogue of Fugitive Prints 1538-1687*, (London: Wellcome, 1999) p. 104.

[189] The sequence of flaps is only visible in the copies that present all the flaps intact and in the original order. This could be observed in the copy of the volume in the collection of the Wellcome Library (EPB 2731/D/2).

"winter garden" *hortus hyemalis* denoted. That procedure entailed not just the desiccation of plants by pressure of the fresh organic matter against the absorptive dry one of paper, but also the physical combination of dried plants to the support of paper, which lent samples the dehydrated state and the flat form. Paper, therefore, was in some way processing, shaping and delivering real plants as pictures of themselves. The resulting adaptation of plants' state and form to that paper was crucial, as it allowed botanists to examine the aspect and matter of single plants and create a botanical archive for continual comparisons and commonplace practices and cut-outs attested by Aldrovandi's herbarium (fig. 2.4).

Finally, into that same category of enhancement we may include another early type of epistemic object obtained through the direct impression on paper of inked specimens. These rare impressions, which are now called "nature prints", were meant to capture the true appearance of plants. Once obtained, analogously to herbaria, they could be collected, allowing specimens to be organised according to the scholars' needs, then studied and shared.[190] By taking form through the physical contact between the specimen's body and the material of paper, nature prints may appear elementary, although, as we are going to see, they were exceptionally dense in their connotations. Images obtained in that way could not be technically named as representations, but rather should be called signs or, as specified in semiotics by Peirce, indexical signs. That specific category of signs, like footmarks on the sand, are called indexical as they directly point at a referent: the real object they have been in contact with (fig. 2.5).[191] Since the intervention of a maker is limited to ensuring that the contact between the herb sample and the sensitive matter of paper leaves a trace, the force of that procedure as an objective means of visualisation is straightforward. It will also appear evident in this case how, under the botanist's eyes, the material of paper operated along with the object under investigation in generating the impression. As Rheinberger clarifies, indeed, a main characteristic of such a group is that the object under investigation directly partakes as an epistemic object in "a close resonance" with a "particular instrument", which in the case of nature prints and herbaria was clearly paper.[192] Whereas paper's material affordances endowed scholars with different ways to pursue the visualisation purpose, it was through these last two techniques of enhancement, as we are going to see, that paper became an influential medium for modern science.

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[190] Federico Tognoni, "Nature described: Fabio Colonna and Natural History Illustration", *Nuncius. Journal of the History of Science*, vol. XX, 2, 2005, pp. 347-370, p. 365.
[191] Charles S. Peirce, "Logic as Semiotic: The Theory of Signs" in Justus Buchler (ed. by) *Philosophical Writings of Pierce*, (New York: Dover, 1955), pp. 98-119.
[192] H. Rheinberger, "Making Visible. Visualisation in the Sciences", p. 17

3.2 Conveying nature from texts to images through nature prints and herbaria

As we have seen so far, paper was an important medium that comprehensively and actively contributed to the study of phenomena in different ways and forms. Reality could be studied on paper not only by means of the written mode, which relied on the symbolic form of texts. Nature, indeed, could be visually explored through representations on paper of different kinds. More significantly, it could be engaged more directly through the indexical form of sign, offered by the direct impressions of specimens also called nature prints, as well as in its corporeal entity, through the desiccated plants of herbaria. We can conclude that much of what visualisation was about in early modern European science concerned and was strictly connected to paper's affordances as a medium. Being paper, a compelling and versatile tool that embraced visualisation in all those forms, we are encouraged to explore in more detail how such a material may have contributed to shape such practices and with what consequences. The 16th century could be described as a phase of active exploration concerning all the possibilities of visualisation offered by paper. Scholars from different fields explored visualisation to various degrees and with diverging attitudes, even up to the complete rejection of the possibility of engaging with nature through its representation on paper. The appreciation of the potential use of images in the science, indeed, was not unanimously recognised at that time. As unveiled by Sachiko Kusukawa, illustrations in the 16th century were intensely contested.[193] The debate concerned not simply the problematic correspondence between illustrations and the authoritative texts of classic authors but, more importantly, also the authority of representation itself. Representation was an arguable instrument for visualisation that relied upon a conventional hierarchy of genres.[194] As Vincenzo Danti (1530-1576) explained, representations usually distinguished between portraying, or representing, things by how they appeared, and imitating nature, or counterfeiting it for how things ought to be seen in the perfect intentional forms of nature.[195] It had to be in that context that, during the 16th century, consequentially to the emerging adoption of herbaria and nature prints among Italian botanists, the material of

[193] Sachiko Kusukawa, *Picturing Knowledge. The Book of Nature* (Chicago; London: The university of Chicago Press, 2012).

[194] On the conventions of representation in the science see: Kusukawa, *Picturing Knowledge*, pp. 8-9.

[195] Vincenzo Danti, *Il primo libro del trattato delle perfette proporzioni, di tutte le cose che imitare, e ritrarre si possano con l'arte del disegno*, (Firenze, 1567) pp. 57-62. Danti's duality clearly originated from Aristotle's distinction between two sorts of arts: those copying nature and those leading to its perfection. See on this: Bernadette Bensaude-Vincent and William R. Newman, "Introduction: The Artificial and the Natural: State of the Problem" in Bernadette Bensaude-Vincent and William R. Newman (eds.) *The Artificial and the Natural: An Evolving Polarity,* (Cambridge Ma: MIT Press, 2007), pp. 1-19, p.5

paper drove a significant transition toward a new form of nature-led idea of scientific representation.

As the analysis of scholars gradually moved from the symbolic form of text to the figurative one, which allowed the visualisation of phenomena, I argue that the unconventional techniques of herbaria and nature prints eased and induced such a transition. This is why those techniques deserve to be considered more carefully. The direct impressions of plants and the conservation of dried specimens within paper sheets were not new techniques at that time. Nature printing had already been explored in Italy in the 14th and 15th centuries, in some illustrated herbals inspired by Arabic works, and was then revitalised during the 16th century. [196] Leonardo da Vinci (1452-1519) famously included the impression of a sage leaf in the Codice Atlantico (1508 ca.) and later in 1520 ca. the Florentine Zenobio Pacini produced a whole volume of composite images of specimens to be used in the context of his trade of "*aromatarius*". Pacini's figures were composed of impressions ingeniously produced from the two sides of individual leaves. Samples were pressed between a folded sheet of paper, pre-soaked in lampblack oil, which inked both sides of the leaf. The impressions thus obtained were hand coloured and integrated by drawing roots and stems (fig. 2.6).[197] Despite having been developed as a practice for herbalists, this technique was mentioned in texts such as Luca Pacioli's *De Viribus Quantitatis* (1498) and later by Girolamo Cardano in *De Subtilitate* (1550), when it started to be adopted by some early Italian botanists.[198]

The art of desiccating samples on paper, in a similar way, had originated as an apothecary practice. Dried samples started to circulate in Italy as early as the late 15th century and, according to Poliziano's words, artefacts of that kind were receiving firm opposition from among the contemporary scholars.[199] Nonetheless, during the 16th century, dried samples spread amid scholars, along with nature prints. This fact should not come as a surprise but was in line with the general and well-known phenomenon of interaction between scholars and practitioners.[200] Pharmacies, in particular, were becoming in Italy lively social spaces for knowledge and the favourite sites of exchange between apothecarists and some scholars.[201] Collecting dry plants

[196] Roderick Cave, *Impressions of Nature: A History of Nature Printing*, (London: The British Library, 2010), p. 21.
[197] Lucia Tongiorgi Tomasi, *An Oak Spring Herbaria*, (Upperville: Oak Spring Garden library, 2009), p. 330
[198] Roderick Cave, *Impressions of Nature*, pp. 24-27. Sergio Toresella, Marisa Battini, "Gli erbari a impressione e l'origine del disegno scientifico", *Le Scienze*, 21, 1988. pp. 64-78.
[199] The case is particularly relevant. In 1493 the humanist Collenuccio sent Poliziano a letter containing two dry specimens that he had identified from a Latin text. Poliziano replied that he had shared them with some scholars and those experts condemned the use of such a form of evidence. S. Toresella, M. Battini, "Gli erbari a impressione" p. 75.
[200] Pamela O. Long, *Artisans/Practitioners and the Rise of the New Sciences 1400-1600*, (Corvallis: Oregon State University Press, 2011).
[201] Valentina Pugliano, "Natural History in the Apothecary Shop", in Helen Ann Curry, Nicholas Jardin et al. (eds.), *Worlds of Natural history* (Cambridge: Cambridge University Press, 2018), pp. 44-60.

on paper sheets thus became especially familiar in centre Italy among some early botanists such as Giovanni Manardo (1462-1536) and Luca Ghini (1490-1556) and was widely adopted by Aldrovandi, whose collection today lists around 5000 samples.[202] It was only at the beginning of the 17th century that the Flemish anatomist Adriaan van den Spiegel (1578-1625), having witnessed those techniques in Padua, described them in detail on the pages of his *Isagoges in Rem Herbariam* (1606).[203] Such an acknowledgement by the Flemish scholar, which followed decades of personal use especially among Italian naturalists, should not be overlooked. The volume, written in Latin, was clearly targeting the international elite of European scholars, to whom he favourably indicated the practices as ancillary to the direct observation of plants, when those were not available. Van den Spiegel, indeed, indicated them as part of good practice for botanists in order to conserve and analyse specimens for their studies especially in the winter months.[204] In other words he was promoting the formalisation of those techniques for the learned to adopt them widely as a collective methodology, one which many in Italy were already valuably pursuing. The actual significance of taking impressions of leaves and desiccating plants in relation with the medium of paper, however, may be easily overlooked. Therefore, in the following section, I am going to consider how those techniques, in the most practical way, were becoming influential tools of knowledge for the Italian scholars through the direct engagement with paper.

3.3 Printing leaves and desiccating plants: a glimpse of nature

In the same years, when Van den Spiegel was first describing to the scientific community the techniques of nature prints and herbaria, Fabio Colonna (1567-1640) was freely engaging with nature printing. During the very first decades of the 17th century he produced a large collection of loose impressions, which he called *iconae,* that are today bound in two volumes housed in the Blickling Hall Library, in Norfolk.[205] The impressions made by Colonna are extremely significant for the development of the scientific representation, as he evidently explored them for their nature-led representational significance (fig. 2.7). These were obtained from combining the bare impressions of inked samples with the drawing of stems and other hand coloured details. The result was a collection of hybrid figures that may seem analogous to those created by the Florentine parfumier Pacini almost one century earlier. Colonna's

[202] On the early diffusion of herbaria in Italy see: S. Toresella, M. Battini, "Gli erbari a impressione", p. 72.
[203] Adriaan Van den Spiegel, *Isagoges in Rem Herbariam libri duo*, (Padua, 1606) pp.79-81.
[204] Adriaan Van den Spiegel, *Isagoges in Rem Herbariam*, p. 78.
[205] Blickling Hall, Library, NT 3070960.

impressions, however, were very different from Pacini's ones. They were not meant to remain confined to the curious workshop practice of a zealous herbalist, rather they were functional to Colonna's personal exploration of natural phenomena. Colonna was indeed a naturalist with wide interests and an early member of the Accademia dei Lincei.[206] Unlike Pacini's impressions, which were vividly coloured so as to evoke the aspect of real plants, Colonna's impressions were left bare and his hand only intervened to incorporate them into a naturalistic composition. The prodigy of those traces seems to be the theme of his *iconae*. His acute contemplation of the way the impressions were generated on paper had to be crucial and the observation of that process is very possibly what led him to unravel the enigmatic morphology of fossils. In 1616 Colonna resolutely contested the traditional theory of fossils as *lapides figurates*, or figural stones obtained by an aberration of nature. For the first time, he correctly described them as the result of a natural process caused by the sediment of an organism on a supple soil, later petrified.[207] It is not hard to see how that soil, which he described as "once supple and muddy", may have recalled the primary state of paper's pulp. [208] Clay had to be seen as a receptive matter which, analogously to paper, was able to retain the memory through contact. In a very practical way practice, his botanic impressions may have suggested to him how a similar process of superimposition could have resulted in the formation of fossils. After all, Colonna had been experimenting with nature printing for some time before he developed his own theory of the origin of fossils. Moreover, he had to regard the technique as highly valuable, to the point that, in 1606, he wanted some etchings to be drawn directly from his *iconae*. Those impressions, indeed, have been recognised as the prototype for the illustrations of his volume *Minus Cognitarum Stirpium*.[209] The influential role of the practices of nature prints in the development of botanic representation could not be clearer.[210] On the one hand, the technique of *horti sicci* was already transforming real plants into two-dimensional pictures of themselves; on the other hand, nature prints, as derived from impressions mechanically produced from contact, were leading to a new form of naturalism in representation. In order to appreciate the influential role

[206] David Freedberg, *The Eye of the Lynx. Galileo, his friends, and the beginning of modern Natural History,* (Chicago: University of Chicago Press, 2002), pp. 113-114.
[207] Nicoletta Morello, *La nascita della Paleontologia nel Seicento. Colonna, Stenone e Scilla*, (Milano: Franco Angeli, 1979) pp. 28-33.
[208] "Olim terra tenui et lutosa" Fabio Colonna, "De Glossopetris Dissertatio" in Fabio Colonna, *De Purpura* (Roma, 1616) pp. 31-39, p. 31.
[209] Federico Tognoni, "Nature Described: Fabio Colonna", pp. 366-367.
[210] Several authors have suggested the possibility of that connection although their studies never contemplated the role of paper: Luca Zucchi, *Lo Specchio in Frantumi: Linneo e la Storia della Rappresentazione Botanica*. Annali dell'Università di Ferrara, n.s., III, (Ferrara: Università degli studi di Ferrara, 2001). Lucia Tongiorgi Tomasi, "Dall'Essenza Vegetale Agglutinata all'Immagine a Stampa: Il percorso dell'illustrazione botanica nei secoli XVI-XVII", in *Luca Ghini. Cinquecento Anni di Scienze Botaniche (1490-1990)* Museologia Scientifica, VIII, n. 3-4. (Imola: Associazione Nazionale Musei Scientifici, 1991), pp. 271-295. S. Toresella, M. Battini, "Gli erbari a impressione", pp. 64-78.

of those techniques, it is important to consider that they had been carried out for decades within some scholars' routines. The continued familiarity with those practices gradually had to lessen the subjective intermediation of the human eye and hand, moving the representation toward an idea of objectivity. In the most practical way, therefore, they were contributing to overcoming the major impasse represented by the conventions of imitating and copying.

As the case of Colonna notably suggests, the adoption of such techniques had another significant implication, which contributed to a new shift in the science. Besides offering the possibility of new forms of representation, those techniques were drawing the attention of the learned toward the physical and material essence of nature. The emphasis on the properties of organic matter, diversely implicit in both those techniques, was in some way unlocked by paper and through paper. The process for makings nature prints, as Colonna recognised, implied that paper, rather than being an inert support, was an active substance. When aptly induced, paper's matter was able to receive and retain a figure from the contact with an organic body, thus "executing" its most faithful depiction. It was nothing less than a natural process. Herbaria were no different in that sense. The material of paper was also able to substantially transform the flesh of plants: by absorbing their natural moisture and combining it with their organic matter, it was able to stop their decay. The desiccated herbs that once supported the work of herbalists were now opening the eyes of botanists. As scholars were meticulously preparing, handling and scrutinising their herbaria, their samples on paper underwent dramatic changes. Leaves were thinning their flesh and exposing their frame while losing colours and life. They were offering to them an extraordinary instance of meditation on the transformation of organic matter from life to death, all of which unfolded in front of their eyes, under the effect of a permeable paper sheet. As Findlen and Toledano have recently indicated, the spreading practices of making preparations in order to preserve specimens became a norm among 18th century scholars and contributed significantly to nurture the scientific knowledge of materials, along with the understanding of their properties.[211] However, I believe that such an analysis is missing a far broader nexus and the widest implications represented by the whole of the early techniques for visualization based on paper. Indeed, while on the one hand paper was conditioning the practices of visualisation among the scientists, on the other the same material of their books, notes and scraps was concurrently driving them to directly engage with nature. Being adopted to convey nature in textual, visual and physical forms, paper guided their interest right to the material core of nature and, in doing so, it was steering the course of science into a new phase.

[211] Paula Findlen and Anna Toledano, "The Materials of Natural History", in Nicholas Jardine and Emma Spary (eds.), *Worlds of Natural History*, (Cambridge: Cambridge University Press, 2018), pp. 151-169.

3.4 The Lincean technology

It was not accidental that Colonna was among the first affiliated to the Accademia dei Lincei, founded in 1603 by the young Federico Cesi (1585-1630) with some friends who had come to share a common new vision. Direct observation was at the core of the Linceans' method for the study of Nature although, in practice, that was never enough.[212] We may consider how their commitment was pursued through an ambitious plan for the visualisation of nature that embraced the technology of paper. Drawings were already considered instrumental for scholars such as Aldrovandi, who keenly commissioned their execution by driving artists' visions through his scholarly-led naturalism.[213] Nonetheless, drawings became distinctively crucial for Federico Cesi. Made primarily from 1605 to the 1620s, they gradually became more and more analytic in the attempt to penetrate the inexplicable and infinite conformations of nature that emerged from the lenses of first microscopes (fig. 2.8). Naturalism, in those drawings, was aimed at bringing the truth of nature forth in a way that had never been experienced before. After Cesi's premature departure in 1630, those visual studies entered the collection of Cassiano dal Pozzo, the personal secretary to Pope Urban VIII's influential nephew, Cardinal Francesco Barberini (1597-1679). As a fellow Lincean, Cassiano's personal investigation of the natural world could have not been more coherent with Cesi's vision.[214] It is significant that Cassiano, later in his life, referred to the vast collection of drawings he gathered, with the name "museo cartaceo", or paper museum, as it has been called since then.[215] Such a designation, referring to the encyclopaedical ambition of recording on paper any interest a contemporary virtuoso and connoisseur might have had from nature to antiquities, could not have been more appropriate. The actual sense of that definition can be appreciated when looking at some of those representations in detail. In Cesi's drawings some details that required a darker background to offset the white linty matter of a subject, such as the inner growth of a cotton's capsule, were already rendered pictorially by the application of a contrast pigment (fig.

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[212] D. Freedberg, *The Eye of the Lynx,* pp. 285-286.

[213] Aldrovandi was regularly indicating to artists what they should depict. Alessandro Alessandrini et al. (ed. by) Natura Picta: Ulisse Aldrovandi, (Bologna, 2007), p. 29. On the subject of Aldrovandi and his drawing's proto scientific value see: Angela Fischel, "Drawing and the Contemplation of Nature" in Horst Bredekamp, Vera Dünkel, and Birgit Schneider (eds.) "The technical image: a history of styles in scientific imagery" (Chicago : The University of Chicago Press, 2015), pp. 170-181.

[214] Luigi Guerrini, "Federico Cesi and the Syntaxis Plantaria", in Brent Elliott (ed. by) *Flora: Federico Cesi's Botanical Manuscripts*, (London: Royal Collection Trust, 2015), pp. 18-61, pp. 23,33

[215] "Questo Museo, dirò Cartaceo, è diviso in molti tomi" wrote Cassiano in 1654. For a full transcription see: Anna Nicolò, Francesco Solinas, "Cassiano dal Pozzo: Appunti per una cronologia di documenti e disegni (1612-1630)" in Les nouvelles de la république des lettres, II, 1987, pp. 59-110, pp. 96-97. Francesco Solinas, *I Segreti di un Collezionista: Le straordinarie raccolte di Cassiano dal Pozzo* (Roma: DeLuca, 2000), p. 121.

2.9). The chromatic grounding of paper was a well-known technique to artists, but with Cesi's drawings, thus, such a technique acquired an investigative function.[216] In Cassiano's drawings the same result was obtained by using coloured sheets (fig. 2.10). Paper's neutral tone was meant to enhance the lifelike features of the portrait of nature and, therefore, darker sheets were used to support light tones and vice versa.

Intriguingly, one drawing among all of them casts a light on the way those depictions were conceived as visualisations through paper, rather than simple representations on that material. The study, aimed at illustrating the nature of asbestos, testifies to the most genuine intention to render the object under investigation through the substance of the sheet. For such a drawing, a particular sheet of blue paper was chosen that presents a perceptible entanglement of lint in its pulp (fig. 2.11a). The effect, seen in the flesh, is remarkable (fig. 2.11b). The fuzzy texture of that sheet somehow intuitively recalls the distinctive fibrous nature of asbestos and seems to be aimed at expressing, on a tangible level, the fibrous quintessence of the uncanny material therein represented. It is hard to believe that the acute scrutiny of a Lincean like that of Cassiano, who commissioned the drawing, might have overlooked the minute conformation of that peculiar paper with respect to the subject it was carrying. In fact, it might appear to be the amusement of an erudite virtuoso, if we neglect to consider that not only was asbestos among the many ontological interests of the Lincean, but likewise was paper, as we are going to discuss in the next chapters. Had he intentionally planned to have the drawing made on such a particular sheet, as it might be reasonable to think, we should conclude that the support was conceived as an integral part of that visualisation plan, as if paper itself was accredited its own representative function. This must have been what he meant when he coined the expression "paper museum". Therefore, when looking at those pictures, we should observe how paper is not just a neutral background for the images, but rather it emerges as a subtle agent. It is the voiceless essential part of the subject represented, alike the formalin it is the fundamental constituent of a wet preserved specimen. As the organic matter is both immersed and injected with formalin to preserve its lifelike features, likewise paper, in Cassiano's drawings, was the material constituent of those representations and the substance through which a sample from nature materialises under our eyes, as if it were emerging from it (fig. 2.12).

Such a distinctive way to conceive images was not atypical to the eyes of those akin to the Lincean Academy. A resonant fascination with the material support of those drawings was verbalised by a contemporary. The Jesuit botanist Giovanni Battista Ferrari (1584-1655) knew

[216] The technique, described by Cennino Cennini in his "Libro dell'Arte" (late 14th/early 15th century), was widely known and used by Renaissance artists such as Leonardo da Vinci.

Cassiano well personally, along with his prominent collection. They both pertained to the entourage of the Pope and especially the Cardinal Barberini, for whom the Jesuit undertook the role of horticultural advisor for his botanic garden.[217] Ferrari harboured an impassioned appreciation for Cassiano's drawings, which he wanted to copy, for the etchings to be included in his publication, as widely studied by David Freedberg.[218] His admiration for the true-to-life rendering of those illustrations of plants and fruits was openly addressed in his 1646 volume on citrus. In *Hesperides*, Ferrari praised the author of many of Cassiano's drawings, Vincenzo Leonardi (1590ca.-1646), for the talent of "engendering nature with his own art". Such a "miraculous" veracity, in his words, resulted in a metaphor which described Leonardi's fruits as "growing in the paper in the same way as in the soil".[219] The expression may appear a singular figure of speech, but it makes clear sense in the context of the Linceans' vision of paper as a scientific medium of materialization. He certainly wanted to compare the objectivity of Leonardi's representations to a spontaneous process of nature and, in doing so, he hinted at the action of paper as a similarly generative substance as that of soil. That vision, therefore, was coherent with Colonna's experience. Such a similarity between paper and ground, as articulated by someone who experienced and had expounded the generative power of soil in his other volume on floral horticulture, is worth being considered with more attention. Ferrari, indeed, referred to the same metaphor several times in his writings. With an analogous connotation to the fidelity of representation, he affirmed that the flowers illustrated within the renowned volume *Hortus Eystettensis*, "bloomed on paper, which is the ground of glory, more beautiful and durable than on the native soil".[220] By alluding to durability with regard to the active role of paper, which minimised the intercession of the painter, Ferrari suggests between the lines that the representation was now being embraced as an authoritative means of visualisation in botany, based on objectivity, which was coherently achieved through herbaria and nature prints. Indeed he gave a full description of those two practices in his volume, explaining how they help plants and their features to be preserved within books "without the toil of writing", as he specifies.[221] By contemplating the figurative means as an alternative to the symbolic form

[217] Ferrari was the consultant for the Pope's gardens and for his nephew, Cardinal Francesco Barberini's botanic garden when Cassiano was his private secretary.
[218] D. Freedberg, *The Eye of the Lynx*, pp. 50-53
[219] Giovanni Battista Ferrari, *Hesperides sive de Malorum Aureorum cultura et usu. Libri Quatuor*, (Roma: 1646) p. 69. "Vincentius Leonardus: Naturam arte geminas, Vincenti, dum vera fingis, quae volumini huic appingis poma: novoque prorsus miraculo efficis, ut aeque in papyro ac in solo nascantur."
[220] "Queste in carta, cioe' nel suolo della gloria, pare, che molto piu' leggiadre nascano che nel terreno natio" Giovanni Battista Ferrari, *De florum cultura Libri IV* (Roma: 1633) translation: G. Battista Ferrari, *Flora overo Cultura di Fiori*. (ed. Roma: 1638) p. 438.
[221] "Hor'affine di perpetuare i fiori per via di libri senza travaglio di scrivere", G.B. Ferrari, *Flora overo Cultura di Fiori*, p. 434

of text, Ferrari's argument was thus cutting across the range of possibilities to convey nature on paper, from the representational one of drawings and prints to the indexical one of nature prints, down to the real object in its desiccated form. In his own experience, paper clearly was the material ground of his scientific vision. Such an emblematic sense of paper as soil, however, was not limited to those forms of scientific visualisation, but also significantly radiated into his practice. Ferrari was a fine scholar immersed in the practical art of horticulture, about which he gave accurate instructions in his writings. Having personally planned some of the most prominent botanic gardens himself, he knowingly advised on designing a garden by planting it "on paper before doing it in the soil" and then "once you have planted on paper, in due time, you can do it in the garden". [222]

4. The rise of paper technology

In order to appreciate the extent of the experiential knowledge of paper among Italian naturalists, as explored up to this point, my analysis needs to be contextualised. It would be reasonable to wonder how we should interpret the facts described so far in terms of a more general progression of knowledge. To address that question, it may be necessary to explore how it could be possible for a material that has been in the hands of people for centuries to suddenly assume such a significant position and, finally, where such a powerful engagement with paper originated from. These questions are going to be addressed in the following two sections from two different perspectives. The first one focuses on the cognitive instance as offered by the material engagement theory, while the second one will briefly contextualise the scientific practice on paper with regard to the artisanal one from which it derived and to which it intertwined.

4.1 The cognitive shift in the modern science

The adoption of paper among the botanists as a medium that conveyed nature through textual and figurative means, up to the inclusion of the real specimens with herbaria, could be read under the aspect of a cognitive progression within the specific "knowing system" of

[222] "Chiunque vorra' ben piantare, pianti prima in carta che in terra". "Dopo che haverai, come si e' detto, piantato in carta, vientene in tempo debito a piantare dell'horto." G.B. Ferrari, *Flora overo Cultura di Fiori*, pp. 213, 221

European science.[223] Malafouris' material engagement theory, which explored the role of human engagement with the material environment in determining human cognitive development, provides the theoretical ground for embracing my analysis.[224] An enlightening case is represented by the instrumental use of clay in the Neolithic development of the concept of numbers.[225] Such a concept, which is only marginally innate, gradually developed from the early use of clay tokens, as proto-signs, through their indexical impressions, up to their representation in the form of iconic signs, and ultimately led to the adoption of inscriptions of a symbolic nature, arbitrarily given.[226] Since the matter of clay could be modelled, impressed and traced, that abstractive process developed through a long-protracted handling that led users to explore clay's material affordances along with their potential meanings (7000-3000 BC).[227] Such a progression, beyond its narrow functional significance, delineates one of the earliest cognitive leaps for humankind which, prompted by clay, brought to the symbolisation of the concept of numbers.[228]

We may notice that an analogous process, concerning the engagement of scientists with paper, unfolded in the opposite direction. This brought early modern scientists to engage with the instrumental use of paper and, moving from the symbolic form of text, to explore the functionality of visual representation. That phase could be identified with the debate over the authority of representation in the 16th century, in which the sense itself of iconic sign was contested but, at the same time, also explored. Subsequently, through the indexicality of sign, as offered by the technique of nature prints, they could approach a more reliable form of representation and they finally approached the real world of nature with herbaria. Considered in these terms, such a process may represent a significant cognitive shift: one corresponding to that complex development that is generally indicated as the rise of modern science. The material engagement theory, however, is even more accurate in tracing the way such a cognitive process emerges. As Malafouris clarifies how human engagement with the material world unfolds, we understand that the act of making, triggers such a cognitive process. This allows us to read historical events even more clearly. In particular, the dynamics of making leads the maker to merge with his tool, or to "extend" his plastic mind. As a consequence, his own

[223] On the concept of "knowledge systems" see: David Turnbull, "Reframing knowledge and other local knowledge traditions", *Futures,* vol. 29, no. 6, 1997, pp. 551-562.
[224] Lambros Malafouris, *How Things Shape the Mind. A Theory of Material Engagement*, (Cambridge, MA: The MIT Press, 2013), ed. 2016 p. 235.
[225] L. Malafouris, *How Things Shape the Mind*, pp. 106-118.
[226] The theory is based on Peirce's theory of signs that distinguishes them in indexical signs, iconic signs and symbols in a gradual detachment from the referent object and ultimately brings to the arbitrariness of symbols.
[227] L. Malafouris, *How Things Shape the Mind,* p. 112.
[228] L. Malafouris, *How Things Shape the Mind,* pp. 112-115.

actions are led by the sensorial feedback derived by his sense of a material.[229] In other words, the act of making causes the maker to think in consonance *with* his own tool and *through* his own tool, which in turn raises his awareness about the tool itself and about himself.[230] I believe that the description of such a dynamic helps to define the pattern of how paper was embraced within the scientific field from the late 16th to the early 17th centuries. In the 16th century, different forms of visualisation on paper were controversially explored, such as fugitive sheets, drawings, prints and preparations. However, two categories of epistemic objects, herbaria and nature prints, may have aroused a way forward. Those techniques started to legitimise representation as an integral and fundamental part of the formalisation of a collectively accepted scientific methodology, which related more directly with the objects under investigation. Such a crucial stage, which may have culminated with the publication of the *Isagoges* by Van den Spiegel in 1606, represented the validation of a practice and its turning point. At the same time, the instrumental adoption of paper was already raising a growing awareness about the potentialities offered by such a material medium. In the development of the material engagement theory, that moment of awareness, which concerns the affordances, or the "material agency" and drives intentionality, is crucial. That agency, indeed, "is not something to be given but something to become realized".[231] It is not easy to trace in historical terms when such an awareness of the material agency of paper started to emerge. It may have first occurred within an individual dimension, especially among those users who early engaged with either herbaria or nature prints since, as we have seen, those techniques in particular highlight paper's material properties. The case of Colonna's experiential understanding is exemplary of this. The way he envisaged the formation of fossils in nature may indicate how he discerned the process of nature printing from the point of view of the material agency of paper. Such an awareness had also to be what led Galileo, only four years after Colonna, to intentionally conceive his system of projection on paper in order to capture a magnified vision and produce copies of it. Intentionality, as Malafouris indicates, is indeed intertwined with the material affordance and emerges, along with the perceived material agency, by means of material engagement.[232] The result of such a process is that paper, through its material affordances, was becoming a cognitive interface between naturalists and nature: one that could be wittingly turned into a proxy matter for the real world. It was by virtue of such a material

[229] L. Malafouris, *How Things Shape the Mind*, pp. 222-226.
[230] L. Malafouris, *How Things Shape the Mind*, p. 175.
[231] L. Malafouris, *How Things Shape the Mind*, p. 148.
[232] L. Malafouris, *How Things Shape the Mind* p. 149

consciousness that paper, from being used as a simple tool, could be fully embraced as a key technology of modern science.

4.2 The paper technology between the artisanal and scientific practices

As we have seen, the techniques of nature prints and herbaria were not devised by scientists. Botanists, rather, embraced their use through their exchanges with herbalists and apothecarists who had first explored their utility in the context of their own trade. This was possibly the last and culminating step in the gradual process of legitimization of representation and, as studied by Pamela Long, Vesalius had already adopted several representational techniques from the practical treatise on architecture by Sebastiano Serlio (1475-1554) for the *Fabrica*'s didactic plates.[233] In more general terms, it will be reasonable to highlight that the methods for visualisation on paper adopted by scientists mostly originated within the practitioners' sphere in the form of aiding tools and instrumental techniques related to their own activity. From there, those techniques transited to the scientific sphere as they acquired new applications within the epistemic purpose of scientists. An application of paper within the conception of Cassiano dal Pozzo's paper museum is exemplary of such a transition. Cassiano himself, indeed, indicated that the 16th century representation of Roman artefacts is a paradigm for the representations that he also finalised in his own studies. He especially mentioned the work carried out by the architect and antiquarian Pirro Ligorio (1513-1583) who had investigated the Roman past as a crucial inspiration for his own idea of a museum of paper.[234] Ligorio's drawings of antiques, as well as those made by other 16th century artists, were extremely valued by contemporary connoisseurs and Cassiano, indeed, owned several copies of them in his own collection (fig. 2.13).[235] Those illustrations, which primarily represented any sort of Roman relic, antique coins and measuring artefacts, constituted a favoured method of investigation of antiquity that allowed those findings from excavations to be conveniently studied in their comparisons and in relation to written sources.[236] The advantages of such a method were evident as antiques were often presented systematically in a classificatory order

[233] Pamela O. Long, "Objects of Art/Objects of Nature. Visual Representation and the Investigation of Nature" in Pamela H. Smith & Paula Findlen (eds.), *Merchants & Marvels. Commerce, Science, and Art in Early Modern Europe* (New York: Routledge, 2001), pp. 63-82, pp. 74-79

[234] For a transcription of Cassiano's text see: Amanda Claridge and Elena Vaiani, "Introduction", Elena Vaiani (ed. by) *The Antichità Diverse Album. The Paper Museum of Cassiano dal Pozzo. Series A – Antiquities and Architecture* (London: Royal Collection Trust, 2016), pp. 15-57, pp. 15-16.

[235] Amanda Claridge and Elena Vaiani, "Introduction", pp. 20-22

[236] Stefania Pafumi, "Introduzione" in Pirro Ligorio, *Libro dei pesi e delle misure e dei vasi antichi*, ed. by Stefania Pafumi (Roma: De Luca, 2011), pp. IX-XXX, p. XIX.

as a tableaux. The method, therefore, was aimed at extending the knowledge of the glorious Roman past through its material culture. This was valuable knowledge that did not consist just of a simple source for erudition but could be usefully and creatively applied to the contemporary arts. The tableaux's pictorial arrangement, which essentially embodied the idea of classification itself and facilitated the study of variations, as has been recognised, was thus functionally adopted by Cassiano within the scientific method of visualisation of nature (fig. 2.14).[237] It should not be a surprise, therefore, that such a powerful modality of representation on paper was integrated into the study of nature, turning it into a scientific convention with its own significant and long history.[238]

More importantly that same genre recurred through the centuries not only within the scientific practice but also in the artisanal one. As an example, we can trace that same method of representation much later, in a late 18th century pattern book made by British ceramic manufacturer Hartley, Greens & Co. held in the collection of the V&A.[239] By looking at the representations in the pattern book, it may be difficult to ascertain whether that type of depiction originated only from the artisanal tradition or was, as it seems, filtered from the scientific modality of illustration (Fig 2.15a). When browsing those pages, indeed, we can clearly see how that kind of representation on paper assumed a new practical function. It had become instrumental to the methodical and almost scientific approach of potters' artisanal work aimed at designing the production itself as a system (fig. 2.15b). Measurements and projections of different types characterise the multifarious representations within that workshop pattern book that also harness paper in its physical form (fig. 2.15c, 2.15d). The range of systematic forms of representation that those drawings present is significant. It was embraced at a crucial time when the ceramic craft in England was just turning into a production system for serial manufacture: "a self-consciously modern, scientific Industry", as Glenn Adamson defined it.[240] That genre of representation on paper, therefore, would deserve to be studied in more detail in relation to the parallel development of scientific illustration. Nonetheless, for the limited purpose of my research it will be important to consider that the instrumental use of paper as a visualisation technology had its own progression that intertwines the scopes of science and craft. In particular, paper significantly shifted from the hands of artisans to those of scientists

[237] Stephanie Moser, "Making Expert Knowledge through the Image Connections between Antiquarian and Early Modern Scientific Illustration", *Isis: A Journal of the History of Science*, vol. 105, No. 1 (March 2014), pp. 58-99.
[238] On that type of representation see: Margarete Pratschke, "Arranging Images as a Tableaux", in H. Bredekamp et al. (eds.) *The technical image*, (Chicago: University of Chicago Press, 2015) pp. 81-85.
[239] Pattern book, Hartley, Greens & Co (1778-1792) V&A museum number: E.576-1941.
[240] Glenn Adamson, *The Invention of Craft*, (London: Bloomsbury, 2013), p. 70.

and then backwards as it was embraced for the purpose of either making or knowing, supplementing each other's sphere of use with its distinctive and versatile resourcefulness.

Conclusion

In this chapter we have seen that, from the late 16th to the 18th century, paper was not only a reasonably inexpensive good, but its decreasing cost allowed paper to become a widespread material that was usefully experienced both in Italy and England across the social classes. Paper's distinctive versatility is considered the reason for its many applications. It was through them, and especially those developed within the practice of artisans, that such a medium started to be resourcefully embraced within the visualization procedures of scientists at an early stage, from the late 16th to the early 17th centuries. The chapter thus primarily focused on the instrumental use of paper among scientists, explaining how such a material, having initially become an influential medium of visualization among Italian botanists, played an important role within the rise of the modern science's practice. In particular, I have considered how historiography so far has restricted this analysis on the instrumental use of paper around the application to textual contents. Nevertheless, the role played by the material of paper with regard to the formal inclusion of visual contents went mostly unnoticed. That specific application of paper, as we have seen, was significant. Recognizing the role of paper in such a development is essential in order to understand that its material contributed to shape the methodology of modern scientists, contributing to envision the principle of objectiveness itself on an experiential ground. More importantly for the direction of my own research, the study of the role of the material of paper within the practice of scientists revealed a novel rise in awareness of matter and its properties, along with that of paper itself.

In light of the facts considered in this chapter, we can summarize some important elements concerning the whole argument of my research. The chapter has been conceived while reflecting upon the question on how the awareness of the material of paper originated. That apparently simple question, however, did raise many other issues. In turn, those issues led me to focus on the development of science and its procedures for visualization, which I wanted to address for their actual meaning in practice. With that in mind, I explored the way in which the use of paper represented a significant instance not just for the history of science but also, and especially, for the history of that material. While searching for an answer to my question, indeed, a double perspective concerning paper emerged. As the practices on paper, and the

familiarity with that material among naturalists, affected the way nature went to be visualised within science, that process started to raise the awareness of paper's materiality. Seen from that perspective, paper seems to have somehow determined its own destiny and it gradually appeared clearer to me that science played a crucial role in the history that I am trying to trace. The fact that paper was embraced as a technology of science, which I analysed in this chapter, emerged as a crucial episode to consider within the progression in the history of such a material: one that has been only superficially considered so far. The rising consciousness of paper's materiality exposed by the practice of use thus deeply affected later events. As we are going to see in the next chapter, from the 17th century the way the material of paper was seen changed in turn and a new perception of paper emerged. The consequence of such a change, in turn, affected the way the material of paper was to be explored through the making process and how it was finally redesigned.

Chapter III

Looking at Paper: From the artefact to the material

Introduction

While the previous chapter focused on the use of paper, the theme of this third one is going to concentrate on looking at paper. In particular, the overall argument will address the significant novelties in how paper was perceived and observed in both Italy and England, along with the crucial implications concerning the direct scrutiny of its matter. Considering the awareness of paper that followed its adoption as a technology for modern science, my research will reflect on how, in the late 17th and early 18th centuries, a genuine cognition of paper's nature was in the process of emerging. Such a development was determined by the elite of naturalists who started turning their inquisitive insight towards paper and, looking at its matter in detail, questioned not only its vegetal prime origin but also its distinctive fibrous constitution. Such a step was influential to gain new knowledge about paper's properties, as a result from the structural element of fibres, and it decisively shifted the conception of paper from an artefact to a natural material. Such a shift, I will argue, is significant. It laid the basis for contemplating the idea of redesigning paper from wood, rather than from rags. At the same time, that new conception led contemporaries to embrace paper as a heuristic model. The active properties observed in that humble material thus resulted exemplary to the early exploration of organic matter and human physiology.

Moving from the subject of the previous chapter, therefore, my argument will consider how that shifting cognition of paper occurred and develops through the content of the present chapter in three main parts. These respectively address the perception of paper, the observation of paper, and the heuristic model of paper. In the first part I present how paper, during the 17th century, was commonly seen through the different standpoints of experience and erudition. In particular, I consider the perception of paper expressed by the author Thomas Fuller. His words on paper demonstrate how scholarly knowledge was blended with direct experience. Experience had long connoted paper as an artefact originating from the polluted jumble of rags, one traded by the most marginalised classes. Nonetheless cultured information

gradually raised consciousness about contemporary paper from rags as a writing support among the many analogous artefacts used by ancient and foreign cultures, while stressing its noble function for the transmission of knowledge and the diverse forms and appearances it could take.

The second part considers the different viewpoint emerging from the observations engaged by scientists and naturalists. I argue that, as they started to look directly into the matter of paper, they came to recognize its vegetal nature and fibrous composition, thus shifting the perception of paper from that of an artefact to a natural substance. This part develops in four sections. The first one, comparing the catalogues of the Cospi and the Tradescant museums, considers how the inclusion of exotic samples of paper among the collections of *artificialia* played a role in the transition from scholarly knowledge to a more direct engagement with and observation of paper itself. The second and third sections present the cases of Francis Bacon and Cassiano dal Pozzo respectively, as representative of a crucial phase in the observation of fibres in the first half of the 17th century. The last section defines the final shift in this epistemic process within science that, finally overtaking the artefactual conception of paper, allowed scholars to look openly at its constitution of fibres. Such a perception could be traced from the observation of paper's fibrous structure, which drove the exploration of the cohesive properties of matter, as engaged in by the Jesuit Lana Terzi, and preluded Réaumur's clue for a future redesign of paper from wood, as inspired by the observation of the material made by wasps.

In the third and last part of the chapter my research aims at addressing the unexplored significance played by the observation of paper for the scientific knowledge of organic matter. The argument develops across three sections. In the first one I trace the background for the advances in the scientific cognition of the structural composition of materials in the 17th century, along with the little studied aspect concerning the emerging scientific cognition of fibres. Following the research on Nehemiah Grew, I argue that the results of the analysis of paper's fibres contributed to the contemplation of those within organic matter, since that knowledge might have helped make sense of the first inexplicable visions emerging from the microscope. On such a premise, the last two sections briefly consider the cases concerning the attempts to understand how organic matter worked through the observation of paper's actions. In the first case, I focus on the visualization of the brain's functioning as described by Descartes and Craanen through their pragmatic knowledge of paper. The second case, at the end of the chapter, addresses how the experiential use of paper as a selective filter by chemists and physicians suggested the embracing of that substance as an operative model to fathom the material foundation of some processes of human physiology.

1. The perception of paper

During the 16th century, the nature of paper as a material was far from being questioned. At that time, the substance of paper not only had little relevance to common users, but also to intellectuals and it was not even contemplated by scientists and naturalists. Nevertheless, possibly in conjunction with the rising awareness of paper that followed its adoption as a technology for modern science, as explored in the previous chapter, the substance of paper started to receive some attention. The present section is going to delineate an overview of how, in the 17th century, the perception of paper among the learned with no interest in science mostly spanned between ordinary experience and erudition. That outline will indicate in the scholarly knowledge, originated from Pliny, the source for a gradual interest and a newly emerging perception of paper: that of a universal and multifarious artefact defined by its appearance and versatility, rather than its raw material.

1.1 From "the emblem of men of mean extraction" to the universal artefact

In the chronicle *The Worthies of England* (1662), written by the English historian Thomas Fuller (1608-1661) and edited posthumously, appeared a section devoted to the newly accomplished national manufacture of paper. In that volume the author expressed a significant definition of what paper was through his own eyes.[241] His writing was grounded on a combination of diverse sources: a long-lasting tradition of literature, some quotes from the Holy Scriptures, and a widespread commonplace view. Being a clergyman rigorously educated in history and theology, with little interest in contemporary science, Fuller casted a definition of paper as "the emblem of men of mean extraction".[242] As he articulated his concepts, Fuller reported the conventional progression from the ancient practice of writing on leaves, the bark of trees and sheets of lead, to papyrus defined as the "old naturall paper".[243] That definition was indicated in sharp contrast with the "modern" paper", the "new artificiall" one made from "grinded raggs". Such a remarkable opposition was evidently based on what was conceived of as a major distinction concerning those different raw materials. Therefore, since papyrus came directly from the homonymous plant, Fuller highlighted a substantial difference from

[241] Thomas Fuller, *The Histories of the Worthies of England*, (London, 1662), pp. 144-149.
[242] On the background of Fuller see: William B. Patterson, *Thomas Fuller: Discovering England's Religious Past* (Oxford: Oxford University Press, 2018), pp. 11-13.
[243] T. Fuller, *The Histories of the Worthies of England*, pp. 144.

contemporary paper that, unlike the antique support, was made from the human sourced raw material of rags. On that principle he had to determine paper's artificial status. Fuller, indeed, indicated rags as the "pedigree of paper" and contended that human "art and industry", with God's blessing, was able to turn the impure substance raked from sewers into the refined support for writing. Like other religious authors before him, in that transformation he recognised the divine redemptive process for the poor and needy directly involved in that trade.[244]

Being based on erudite sources and a solid tradition, it is hard to find a definition of paper as obsolete as Fuller's at those dates. Nonetheless, his words represent the last verge of a conception of paper that had been extremely common until then, also familiar to Italian readers, but which was in the process of subsiding. Until the 16th century, the nature of paper was mostly denoted as the outcome of processing rags, which gave paper its most meaningful connotation.[245] On a practical level, such a cognition was clearly based on direct experience and some common prejudices. It had to be usual, both in Italy and, gradually, in England, to witness what the collection of rags was about, and especially who was behind it.

In Italy, after the 1555 papal bull had decreed Jews' "eternal guilt" of deicide, the occupation of that group was restricted to the allegedly immoral activities of pawnbroking and second-hand goods trading. This implies that the collection of rags was primarily carried out by the Jews in a systematic way through their own active trade network. "All the rags travel to the ghetto" said Tomaso Garzoni in 1585, and that group continued to be involved in the occupation until at least the early 19th century.[246] The connotation of impiousness decreed in Italy by the religious authority over the trade in rags was apparently not unusual in England as well. A similar idea of immorality could be traced in that country with regard to ragmen. It is significant that a popular broadsheet, pretending to reveal the deathbed confession of the hangman who beheaded Charles I in 1649, expressly indicated Richard Brandon as a ragman who earned 30 pounds, which clearly recalled the 30 pieces of silver that Judas received for the betrayal of Jesus.[247] As soon as the king's execution started to be intentionally rewritten as the martyrdom of a saint, therefore, the executioner's disreputable act was apparently contrived around the

[244] The same concept could be found in the Italian devotional literature. See: Pietro Buonfanti (from Diego de Estella), *Dispregio delle vanità del mondo*, (Firenze, 1581), p. 328.
[245] Joshua Calhoun, "The Word Made Flax: Cheap Bibles, Textual Corruption, and the Poetics of Paper", *PMLA*, March 2011, pp. 327-344.
[246] Tomaso Garzoni, *La piazza universale di tutte le arti*, (Venezia: 1585) p. 933. Augusto Ciuffetti, *Carta e stracci: protoindustria e mercati nello Stato Pontificio tra Sette e Ottocento,* (Bologna: Il Mulino, 2013).
[247] Joad Raymond, "Popular representations of Charles I" in Thomas N. Corns (ed. by), *The Royal Image. Representations of Charles I*, (Cambridge: Cambridge University Press, 1999), pp. 47-73, p. 60.

common discrimination and the dubious morality of rag collectors.[248] Before the Jews were readmitted in England and started to manage their networks by the late 17th century, indeed, rags were notoriously picked up by the most marginalised classes. The poor, vagrants, and "loose" women who collected rags brought them around to Rosemary Lane in London's East End. That neighbourhood, known for "the rag fair", was one of the most infamous areas of London where rags had long been gathered and traded. A 1703 description defined it as a "heathenish part of the town" where a "tattered multitude" coexisted with the smell of "musty rotten rags and burned old shoes" and in which every misconduct from pickpocketing, receipt of stolen goods, robbery, and prostitution notoriously proliferated in an unruly social environment.[249]

The discrimination, however, was not just moral but also quite reasonably concerned community health. On a very practical level the collection of rags, although vital for the manufacture of paper, was a hazardous activity. The social group involved in it in Italy differed from the English one, however, the conditions relating to that trade had to be somewhat comparable. The physician Bernardino Ramazzini (1633-1714) vividly pictured the repulsive conditions within the ghetto of Padua in his *De morbis artificum* (1700), the first treatise on trade-related illnesses.[250] The physician dwelled on the busy work of Jews in the extremely narrow and dark streets of their overcrowded district where the air was utterly unbreathable due to the dust and intense stink coming from the grimy rags.[251] Respiratory pathologies and scabies, indeed, typically pestered the Jews to the point of being even commonly claimed as their congenital attribute.[252] In the collective consciousness, all of those circumstances connoted rags and whoever dealt with them so deeply that such a negative association flowed into the perceived nature of paper or, as Fuller expressed it, its "pedigree".

Fuller's text, however, was not only based on that ordinary assumption. On a more cultured level, which denoted the intellectual status of the clergyman, his discernment of paper also concurrently relied on a widespread literary tradition related to the historical variety of writing supports. Such tradition, which is openly echoed in Fuller's words, had originated from the Roman author Pliny the Elder (23-79), who first dedicated to writing supports a long chapter in

[248] On the immediate rewriting of the event see: Lois Potter, "The royal martyr in the Restoration" in Thomas N. Corns (ed. by) *The Royal Image. Representations of Charles I*, (Cambridge: Cambridge University Press, 1999), pp. 240-262, pp. 244-245.
[249] Janice Turner, "'Ill-Favoured sluts'? – The Disorderly Women of Rosemary Lane and Rag Fair", *The London Journal*, vol.38 no.2, 2013, pp. 95-109.
[250] Bernardino Ramazzini, *De Morbis Artificum Diatriba*, (Modena, 1700).
[251] B. Ramazzini, *De Morbis Artificum*, pp. 241-247.
[252] Piero Camporesi, *La Miniera del mondo: Artieri, inventori, impostori,* (Milano: Saggiatore, 1990), p. 165.

his *Naturalis Historia*.[253] In a development from the use of palm leaves, the bark of trees, and wax tablets, the Roman author had especially focused on *charta*, the Latin name for papyrus, which was the main writing medium in use at that time.[254] Pliny's account on *charta* was detailed. It combined historical information with the properties of the plant and included the description of the process for transforming it into a writing support. Moreover, Pliny outlined the different qualities of charta in use and, finally, acknowledged its critical function for the transmission of texts to posterity.[255] Pliny's work was extraordinarily influential through the centuries and, with it, the subject of the historical progression of writing supports was disseminated. Since the Renaissance the volume thus significantly fostered the interest in paper and its invention. As the reading of Pliny's text persisted in the early modern period his words are echoed in the content of innumerable later authors and the theme of paper's history developed into the literary convention to which Fuller adhered. Pliny's argument, however, was not simply evoked but it was rather extended by including paper made by contemporaries from beaten rags in a progression line from antiquity. With that intention, in 1494, the humanist Grapaldi mentioned the range of writing supports from antiquity to modern times, introducing the first account of the process for obtaining paper from discarded textiles unknown by ancients. It is in that way that paper went on to be included in the current literary genre on the history of human inventions.[256] Such a development, however, was not always considered as a progressive advancement. As has been noticed, the 1599 work by Guido Panciroli (1523-1599) regarded antiquity to be the repository of some sort of artisanal knowledge lost by contemporaries, and this also concerned the making of writing supports.[257] Nevertheless, until then and except for some rare episodes of direct observation of antique papyrus samples, the only direct experience of historical writing materials was exclusively grounded on the

[253] Gaius Plinius Secundus, *Naturalis Historia, Liber XIII*, XXI- XXIV, 68-89. From: Bostock, John and Riley, H.T. (eds.), *The Natural History of Pliny*, Vol. 3, (London: Taylor and Francis, 1855), pp. 185-191.

[254] Although parchment was already known, it only later supplanted papyrus. Jean Irigoin, *Le livre grec des origines a la Renaissance*, (Paris: Bibliothèque Nationale de France, 2001), pp. 61-62.

[255] Ignace H. M. Hendriks, "Pliny, Historia Naturalis XIII, 74–82 and the Manufacture of Papyrus,", *Zeitschrift Für Papyrologie Und Epigraphik,* 37, (1980), pp. 121–36.

[256] The theme of the invention or discovery of paper developed a proper literary topos that circulated among the intellectuals all over Europe, see: Polydori Vergilii Urbinatis, *De inventoribus rerum libri tres*, 1499 (ed. 1503). no page, cap. VIII and Guido Panciroli, *Nova reperta sive Rerum Memorabilium, Recens Inventarum et Veteribus Plane*, ed. by Heinrich Salmuth (Amburg, 1599). For the sequence of events, editions and translations of Panciroli in Europe see: John Ferguson, *Bibliographical Notes on Histories of Inventions and Books of Secrets*, vol.I, supp.1, (London: The Holland Press, 1959), pp. 39-41. Italian edition: Flavio Gualtieri, *Raccolta breve d'alcune cose piu' segnalate che ebbero gli antichi*, (Venezia, 1612), English edition: Panciroli, *The history of many memorable things lost,* (London, 1715).

[257] On Panciroli's work see: Anthony Grafton, "Renaissance Histories of Art and Nature" in B. Bensaude-Vincent and William R. Newman (eds.), *The Artificial and the Natural: An Evolving Polarity*, (Cambridge: the MIT Press, 2007), pp. 185-210, p. 190

information gathered from the literary sources, while the actual knowledge of paper was limited to the contemporary qualities available and in current use.[258]

A significant change of perspective, overcoming Fuller's perception, had to emerge with the surge in geographic explorations, especially when travellers and missionaries started to observe with their own eyes the variety of writing supports in use among other cultures and reported about them.[259] This fact undoubtedly reflected the generally increasing curiosity for exotica in the 16th century. Such a curiosity, as has been reported, was gradually integrating both the Renaissance's traditional interest in antiquity with the enthusiasm for the world's contemporary cultures and the concept of distance in time with that of geographic space.[260]

The contextual analysis examined so far presents a range of diverging aspects concerning the idea of paper. Considered altogether, those elude a univocal definition of paper, since the sense itself of what was to be considered as paper wavered. An example of such an inconstant perception of paper may be traced to a literary source. When a Japanese ambassador visited the court of Pope Paul V in Rome in 1615, the thin vegetal film used as a disposable tissue to blow his nose did not pass unnoticed.[261] A small treatise on the preceptorship of noble youth reported that the artefact used by the foreigners, analogously to an ordinary handkerchief, was nothing other than an extremely fine and soft membrane manufactured from the bark of an exotic tree. However, the author also recognised that, in colour and consistency, that membrane bore resemblance to the kind of unsized wrapping paper commonly known as "*carta straccia*".[262] Such a candid account suggests that the author was certainly looking at the artefact and its disposable use as an indication of the advancement of that remote civilization. However, and more interestingly, he also effortlessly conformed the European type of paper to that

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[258] Muzio Pansa, writing in 1608, mentioned to have been able to see one example of papyrus as shown to him by Castor Durante. Muzio Pansa, *Vago e Dilettevole Giardino di varie Lettioni di Mutio Panza* (Roma, 1608) p. 7. An Egyptian papyrus was also indicated in the collection of Francesco Calzolari, Benedetto Ceruti, *Musaeum Francisci Calceolari Juv. Veronensis*, (Verona, 1622), p. 711.

[259] Although authors started to report about the foreign varieties of paper by the end of the 16th century, the theme mostly emerged in the 17th century literature. The reference to foreign types of paper are many: Juan González de Mendoza, *Historia de las cosas más notables, ritos y costumbres del gran reyno de la China*, (Barcelona: 1586), p. 125. Bonifatio Vannozzi, *Della suppellettile degli avvertimenti politici, morali, et christiani*, vol.2 (Bologna, 1610), p. 399. Daniello Bartoli, *Dell'Historia della Compagnia del Giesu: L'Asia*, vol. I (Roma, 1653), p. 57. Gabriel Magaillans, *A New History of China, containing a description of the most considerable particulars of that vast empire*, (London, 1688), pp. 137-8.

[260] Daniela Bleichmar, "Seeing the World in a Room: Looking at Exotica in Early Modern Collections", in D. Bleichmar and Peter Mancall (eds.), *Collecting across Cultures Material Exchange in the Early Modern Atlantic Wo*rld, (Philadelphia: University of Pennsylvania Press: 2011), pp. 15-30, p. 17.

[261] Lelio Pascali, *L'aio del capitan Lelio Pascali*, (Roma, 1641), p. 257.

[262] "Di questo spurgarsi il naso in un fazzoletto e poi tornarselo a mettere nelle bisacce si stomacavano e scandalizzavano quelli Giapponesi, che a tempo di Paolo V vennero a Roma: Perche' essi quando se lo spurgavano, facevano ciò con alcune pellicelle d'arbori del loro paese tanto sottili, e di tal tenerezza, che in questo, e nel colore non erano punto differenti dalla nostra carta straccia: e ogni volta che se l'erano spurgato, stracciavano della detta pellicella tanta parte, quanta ne restava imbrattata, e la buttavano via, rimettendosi il restante nelle bisacce". L. Pascali, *L'aio del capitan Lelio Pascali*, p. 257

vegetal film, as if his own concept of paper extended to encompass that rather different material. Therefore, from the encounters with other cultures, paper was gradually emerging as a universal artefact. Regardless of the raw material it was made of, paper could be apparently defined by its physical appearance and versatility of use, all of which, in the eye of an European observer, reflected the culture such an artefact belonged to.

2. The observation of paper

Besides the ordinary idea of paper considered so far, a new perception of paper was emerging from the direct observation of artefacts. Such a different view on paper resulted from the observations of botanists and naturalists, who had turned their interest towards the humble material made from rags and started looking at its substance in more detail. They thus went on to investigate not only the vegetal origin of its matter but also its fibrous constitution. Considered from this perspective, the act of looking at paper decisively shifted the cognition of paper from being the simple artefact obtained from processing rags to embodying the principles of a proper matter, organic in nature. The shift may appear a mere change of a viewpoint, however, its significance was substantial. The change in the perception of paper from an artefact to a natural substance is what led to the contemplation of the reason for its distinctive material properties. That proved a major advancement in the scientific knowledge of fibrous substances and also a standpoint from which to envision the possibility of redesigning the material of paper to be manufactured directly from a vegetal source, rather than from rags.

2.1 Collecting paper between erudition and observation

Given the circumstances of the rising interest in paper as a multifarious artefact that pertained to different cultures, it was inevitable that some erudite collectors wanted to gather exotic samples. Therefore, it did not take much time for paper to appear displayed in some contemporary cabinets of curiosity, among the artificial rarities. The implications of such a practice were certainly significant for the change to a new first-hand perception of paper. Owning and displaying it, indeed, inherently prompted direct observation, inviting appraisal from observation and bookish knowledge: a determinant step in the overview of future developments.

It is worth mentioning here two different collections, one Italian and one English, that housed some paper samples: the first gathered by the Bolognese nobleman Ferdinando Cospi (1606-1686), and the other one by the English collectors and naturalists John Tradescant the Elder (1570-1638) and his homonymous son (1608-1662). Both of the collections, as a custom, were celebrated through the printed editions of their own catalogues, which allow us to speculate on the respective significance of the exotic papers among rarities.[263] The Cospi museum, into which the collection of Ulisse Aldrovandi had been merged after his death, was an illustrious one and its catalogue was edited in 1677 by the academic and Greek scholar Lorenzo Legati.[264] As Paula Findlen indicated from her studies of the Italian case, the significance of visiting museums and collections at that time was primarily that of experiencing and appreciating objects in person as a complementary practice to the knowledge acquired from books.[265] The Cospi Museum was exemplary of that attitude and its catalogue remarkably reflected the same idea. The volume indeed aspired to convey the experience of the visit as introduced by the famous engraving illustrating Cospi's eloquent gesture of ostentatious display, which encompassed his precious objects along with his dwarf keeper holding one of them in his hands (fig. 3.1). [266] Nonetheless, the details of a volume lying open next to Cospi's figure clearly had to remind the readers looking at that picture that observation was not to be embraced without the erudite knowledge acquired from books.

As a matter of interest, the opening section of *artificialia* mentioned paper after a long statement about the universality of the writing culture in different times and civilizations, and which was meant to introduce the series of exotic books to visitors of the collection.[267] The whole section begins with the conventional reference that elevated books as the invaluable media for the diffusion of knowledge to posterity, as Pliny had first praised them. However, when the text presented the physical observation of objects, the tone turned into an experiential description. The catalogue indicated several aspects of the exotic books, from the obscure characters composing their writing systems to their inks, pigments and bindings. The author also considered each particular paper in comparison with the more familiar type in use in Europe.[268] To define those exotic artefacts, thus he outlined the superiority and weaknesses in consistency, whiteness and responsiveness to ink with respect to the paper he mostly knew.

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[263] Another case of a collection that included several types of exotic papers is the one of Manfredo Settala. Paolo Maria Terzago, *Musaeum Septalianum Manfredi Septalae*. (Tortona, 1664).
[264] Lorenzo Legati, *Museo Cospiano annesso a quello del famoso Ulisse Aldrovandi*, (Bologna, 1677).
[265] Paula Findlen, *Possessing Nature: Museums, Collecting and Scientific Culture in Early Modern Italy*, (Berkeley: University of California Press, 1994), pp. 194-240.
[266] On the social meaning of collections' display see: Jay Tribby, "Body/Building: Living the Muséum Life in Early Modern Europe", *Rhetorica: A Journal of the History of Rhetoric*, vol. 10 (1992), pp. 139-63, p. 154.
[267] L. Legati, *Museo Cospiano*, pp. 184-194.
[268] L. Legati, *Museo Cospiano,* p. 187.

Legati also considered the material origin of those artefacts. For the Chinese paper, as an example, he contemplated the possible use of silk due to the distinctive thinness and smoothness of its sheets.[269] Nonetheless, his observations could not be considered analytical. Today we know that the pages of the pre-Columbian Mexican book, which is still housed in the collection, are made of leather covered in a thick coat of varnish. [270] However, in the eyes of Legati, that fact was either considered irrelevant to readers or went completely unnoticed, since the description of that piece eluded completely such a detail. Therefore, although some physical examinations of the foreign singular types of papers were engaged in, those were undertaken only to some extent. His observations remained apparently subordinate to cultured knowledge as if restrained by its influential weight, whilst the question of the material's nature was not addressed in depth.

The second case of a collection that included paper among its rarities pertains to the English collector John Tradescant the Elder. That collection was started in the first decades of the 17th century and was carried on by John Tradescant the Younger until his death, when Elias Ashmole (1617-1692) acquired it; subsequently becoming part of the Ashmolean Museum.[271] The nature of that collection was very different from that of Cospi. While the Italian collection denoted the assertion of a nobleman's intellectual stature, the one gathered by the Elder Tradescant was meant to secure his social ascent among the English elites.[272] Along with his son, the Tradescant were prominent horticulture practitioners who personally travelled abroad searching for unknown botanic specimens and other rarities.[273] Accordingly, the catalogue of that collection, written by Tradescant the Younger and edited in 1656, was a very different type of volume too.[274] It was conceived of as a scant list of items and, despite being organised according to the conventional duality of nature and artifice, it testifies to a diverging vision from the one expressed by Legati. Instead of a range of foreign typologies of books, the section on artificialia only enlisted paper generically named as "Indian". That category consisted of some books made of phillyrea plant and three qualities of paper samples specified through a curly bracket as made of "grasses", "straw" and "rinds of trees".[275] Therefore, although the

[269] Ibidem.
[270] Karl A. Nowotny (ed.by), *Codex Cospi. Calendario Messicano 4094, Biblioteca Universitaria Bologna*, (Graz: Akademische Druck, 1968), p. 12.
[271] Arthur MacGregor (ed.by), *Tradescant's Rarities. Essays on the Foundation of the Ashmolean Museum*, (Oxford: Clarendon, 1983).
[272] Marjorie Swann, *Curiosities and Texts: The Culture of Collecting in Early Modern England*, (Philadelphia: University of Pennsylvania Press, 2001), pp. 37-38.
[273] Jennifer Potter, *Strange Blooms. The curious lives and adventures of the John Tradescants,* (London: Atlantic Books, 2006).
[274] John Tradescant, *Musaeum Tradescantianum or, a Collection of Rarities* (London, 1656).
[275] J. Tradescant, *Musaeum Tradescantianum*, p. 41 and p. 39.

generically foreign provenance of those artefacts was part of their significance, the most relevant aspect apparently related to the organic origin of those papers, along with their diversely sourced raw materials. Such particular attention over the material nature of the samples is remarkable and was certainly related to the personal curiosity of the Tradescants.

Father and son cultivated an impassioned interest in horticulture and both of them had been appointed with the title of "Keeper of the Royal Gardens".[276] More than half of their collection, indeed, consisted of exotic plants, which they grew in the *Hortus Tradescantianus* in South Lambeth. That botanic garden was the repository of the rare specimens they were able to collect during intercontinental travels, through their personal network, especially thanks to their close friendship with John Parkinson (1567-1650), the most prominent botanist in England at the time and apothecary to Charles I.[277] The interest that botanists had in paper was not incidental and it certainly was not for the Tradescants. As mentioned in the previous chapter, the practice of 17th century European naturalists had started to closely rely on paper for the conservation of samples among the pages of their herbaria. Paper, indeed, was crucial to their direct engagement with plants and a means for their study. The Tradescants, who owned a collection of dry specimens, had to share the same familiarity with paper of contemporary botanists.[278] Tradescant the Elder also reasonably knew from the experience of his friend Parkinson that, while paper preserved plants in the dry form, it also kept a main force of their nature alive: the reproductive power of seeds. The botanist indeed recalled in his own treatise of having been able to grow exotic species from the seeds sent to him when still unripe among the rare species desiccated on paper.[279] The fact could have pointed at the intrinsic compatibility of paper and plants. Their regenerative capacity thrived in paper since, after all, they shared the same organic matter and vegetal nature.

The variety of botanic species that constituted the Indian papers had also to be particularly significant for the Tradescants. It might have encouraged them to examine the paper samples and search for some conformity with their original plants, or more simply led them to observe the fibrous traces of vegetal matter trapped in their pulp. Unfortunately, we don't have any precise clue on the interest the Tradescants harboured in those paper samples and we don't have any information about their actual appearance either. None of the paper samples was mentioned among the Tradescants' rarities acquired by Ashmole and we have to conclude that

[276] J. Potter, *Strange Blooms.* p. xv.
[277] J. Potter, *Strange Blooms.*, pp. xxi-xxix.
[278] On Tradescant's herbarium (MS. Ashmole 1465) see: A. MacGregor (ed.by), *Tradescant's Rarities.* p. 356.
[279] John Parkinson, *Theatrum Botanicum*, (London, 1640), p. 1108-9.

perhaps they were dispersed.[280] All we can say is that, rather than their geographic provenance or cultural significance, Indian paper samples collected by the Tradescants certainly had to mean more than the concise list of the catalogue suggests. The vegetal nature of that exotic paper was relevant to those collectors as part of their own interests. We may, indeed, presume that the samples showed certain distinctive features. They might have reasonably presented some sort of fragments of grass and bark of trees to attest to their diverse substances and that the interest of the Tradescants laid with the observation of that singularity of organic matter.

From the analysis of the Cospi and the Tradescant's catalogues, it is possible to conclude that, despite the scant evidence on what the collectors were actually seeing in their exotic papers and on the depth of their scrutiny, those cases are certainly significant. They testify that paper had become an object of curiosity and was at the core of a different interest in-between the erudite knowledge of scholars and the investigation of nature undertaken by naturalists. More importantly, those cases demonstrate that collecting, by entailing a direct engagement with the objects, was inevitably leading collectors to observe what was in front of their eyes, regardless of each one's different perspective. The respective acts of looking may thus appear diverging, yet equally significant. Nonetheless, sidestepping the rhetoric of bulky literature that surrounded the observations of Legati on Cospi's exotic books, we may notice that the Tradescants were reasonably addressing the material concern more accurately, or we may say with a scientific eye, compared to the Italian scholar. In particular, the Tradescants were collecting their samples for what they were made out of and it will not be difficult to recognize in their interest in paper's matter, as assumed from their catalogue, a reflection of the new approach of modern science and the rise of empirical investigation.

2.2 The gaze down into paper

In the same years when Tradescant the Elder started gathering his botanical rarities during his trips overseas, Francis Bacon was writing his *Novum Organum*. Edited in 1620, Bacon's work became a seminal text and it is easy to imagine that Tradescant would have pictured himself during his voyages in the engraving of the emblematic ship sailing beyond the Pillars of Hercules that featured in the title page of Bacon's first edition (fig. 3.2).[281] They clearly shared the consciousness of being at the threshold of a new age. Tradescant had certainly been captivated

[280] There is no mention of the paper samples enlisted in the original catalogue among the surviving pieces of the collection. A. MacGregor, *Tradescant's Rarities.*
[281] Francis Bacon, *Summi Angliae Cancellarii, Instauratio magna. Novum organum* (London, 1620).

by the novel perspective of knowledge envisioned by the inductive process of reasoning that the statesman was favourably advocating.

Although the Novum Organum was a philosophical treatise, it was also rich in pragmatic methodological insights, which strongly encouraged speculation after the direct perception of things and through experience.[282] A main concern in Bacon's work was to delve into the laws of nature by exploring its processes and perceptible forms. Such an approach encouraged him to theorise about an investigation of nature that searched for its smallest clues. This is particularly significant for the present research, since Bacon was putting into clear words a novel attention to the properties of matter that included paper as a key case. Several parts of his text considered fibres as a crucial constituent of specific substances: by looking at their order and direction, Bacon aspired at understanding how matter worked.[283] In a statement of proposal of his work he affirmed: "one must ask of every body how much spirit is in it (…). Likewise the tangible essence (which allows as many differences as spirit), with its hairs and fibres and textures of every kind, is subject to the same enquiry" in order to grasp in those structures their "primary axioms".[284] His method of induction indicated the primary role of active perception in detecting "parallels or physical similarities (…) and connections between things".[285] Moreover, although nature was the object of his enquiry, he saw no reason for not considering artefacts as "useful for information".[286] According to Bacon, indeed, the texture of artificial materials only differed from that of natural ones in its less subtle scale of grain, not for inferiority, as some "superstitious scholars" had rather alleged.[287] It had to be such a genuine and single-minded vision that inspired Bacon to openly shed a new light upon the world and, by turning his gaze downwards to look into paper's subtle substance, verbalise what he saw in its inner structure as nobody else had done before.

Bacon distinguished artificial materials into two main categories: those made of concreted juices, like glass or earthenware, and those made of threads, like cloths, linen, and silk. In his view, the brittle nature of the former ones indicates that they don't hold together well, whereas textiles, being woven, are deliberately arranged in a way that provides a certain resistance. What is important for my research is that, between those two categories of artificial materials, Bacon set a significant distinction for paper. According to him, the intrinsic tenacity of its fibres was a unique feature that made paper the only artificial material comparable to natural matter.

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[282] Lisa Jardine, "Introduction", in Lisa Jardine (ed.) *Francis Bacon: The New Organon*, (Cambridge: Cambridge University Press, 2000), p. XIV-XV.
[283] Lisa Jardine (ed.) *Francis Bacon: The New Organon*, (Cambridge: Cambridge University Press, 2000), p. 203.
[284] L. Jardine (ed.) *Francis Bacon: The New Organon*, p. 108.
[285] L. Jardine (ed.) *Francis Bacon: The New Organon*, p. 144.
[286] L. Jardine (ed.) *Francis Bacon: The New Organon*, p. 152.
[287] L. Jardine (ed.) *Francis Bacon: The New Organon*, p. 171.

As a consequence, due to the property of its substance holding it together by virtue of its constitutive fibres, paper was considered essentially analogous to "the skin or membrane of an animal, or the foliage of a vegetable". [288] From his statements we can infer that Bacon turned to paper, rather than any other man-made substance, in order to reach a deeper understanding of matter itself. The Organon thus elevated paper as a representative formation, which drove Bacon's entire reflection on fibres and made of paper a key substance from which to explore, understand and, potentially, even master nature itself.

Bacon's words had been extremely influential. The observation of paper, far from being incidental, was ingrained into his own vision and the reformation of knowledge that he was putting into words. However, as Mokyr reminds us, while Bacon's work has been remarkably significant to posterity, he represented a transitional figure and "the product of the end of the 16th century".[289] He was not an isolated thinker and his vision was somehow parallel to the investigation of nature pursued in Italy by the early Linceans. The English philosopher, indeed, was not the only one considering paper's substance in the early decades of the 17th century. Although geographically distant from Bacon, in those same years Federico Cesi, was also contemplating the nature of paper in relation to his own enquiry.[290] His interest was conceivably related to the way the Linceans had started to embrace paper as a visualisation technology, as discussed in the previous chapter. In his *Tabulae Phytosophicae*, a compendium of botany and philosophy edited in 1628, Cesi expressly dedicated a passage of his work to paper.[291] While recalling the conventional praise for paper's contribution to the diffusion of knowledge, that material was also presented as the ingenious product of the mutual work of man and nature. His analysis, however, examined paper's nature in more depth. Conceived on a comprehensive basis and with a classificatory aim, Cesi's work presented the many forms in which plants

[288] "Paper is a unique instance of art; a common enough thing. But look at the matter carefully. Artificial materials are either simply woven from upright horizontal threads, like cloth made of silk, wool, linen etc., or made of dried liquids, such as brick, or earthenware, or glass, or enamel, or porcelain and so on; they shine if closely compacted; if not they harden but do not shine. Now everything made of dried liquids is fragile, and not in the least tacky or tenacious. Paper however is a tenacious substance which can be cut and torn; so that it imitates and almost rivals the skin or membrane of an animal, or the foliage of a vegetable, and such natural products. It is not fragile like glass nor woven like cloth; it certainly has fibres, but not distinct threads, altogether like natural materials. And so it is found to have hardly any similarity with other artificial materials but to be absolutely unique. The better kinds of artificial materials are surely those which either most closely imitate nature, or on the other hand masterfully rule her and change her completely." L. Jardine (ed.) *Francis Bacon: The New Organon*, pp. 151-152

[289] Joel Mokyr, *A Culture of Growth: The Origins of the Modern Economy*, (Princeton: Princeton University Press, 2016), p. 78.

[290] Although Bacon knew Galileo's work, the research of the Linceans at an early stage was not influenced by Bacon's work and Cassiano only first mentioned the name of the English philosopher to Cesi in 1626. Gilberto De Angelis, "Notizie inedite sulla prima giovinezza di Federico Cesi: una conferma delle fonti francescane della spiritualità cesiana", in Gilberto De Angelis, Andrea Battistini (eds.) *All'Origine della Scienza Moderna*, (Bologna: Il Mulino, 2007), pp. 17-105, pp. 84-88. D. Freedberg, *The Eye of the Lynx,* pp. 75-76.

[291] Federico Cesi, "Phytosophicarum tabularum" in Federico Cesi et al. (ed. by) *Rerum Medicarum Novae Hispaniae Thesaurus* (Roma: 1649), pp. 900- 950, pp. 922-923.

underwent a transformation to satisfy humankind's needs. That subject was formulated on a large diagram, which was significantly experimenting with the expository potential of paper's medium by eluding the sequential form of discourse (fig. 3.3). The structure of the argument, thus, went on to indicate that paper, although processed from the maceration of discarded textiles, in the first instance had a natural origin and, as such, it was merely made from plants.[292] The sequence of Cesi's diagram implied that paper was essentially a vegetal substance, with rags only representing a transitional stage of the plant's mutable matter of fibres.

Cesi's writings may appear cryptic to interpret, nonetheless his efforts thoroughly reflected the depth of the philosophical enquiry he was addressing. The intensity of his scrutiny of the natural world was part of his wider inquest into the essence of life itself, which clearly represented an incommensurable endeavour. As it has been noted, such an enquiry was leading him to delve into the study of the vegetal matter, where the vital life force of plants was ingrained and distributed, "*fusa ac diffusa*", throughout the whole of their fibrous organs "*fibrosas partes*".[293] Although Cesi's work remained incomplete at his death, his own concern on the manifestations of organic matter, to which paper's nature was related, was carried on by Cassiano dal Pozzo who, as we have seen, acquired Cesi's precious study drawings. Such interest consistently emerges from Cassiano's own drawings. David Freedberg, who studied them, inevitably noticed how the morphologies and consistencies of matter were minutely observed and depicted.[294] Whether in the juice vesicles of a citrus, the delicate gills of mushrooms, or the rugose texture of a raw branch of coral, the structural and perceptive configuration of matter was clearly at the centre of Linceans' investigations. Accordingly, fibres were a crucial element to such an interest, testifying that Bacon's words, although arising from a different milieu, found among the Linceans a likeminded vision. It is not surprising to know, indeed, that Cassiano received Francis Bacon's texts from his French correspondent Peiresc and, following that reading, he suggested to his Lincean fellows that they offer the English philosopher the opportunity to join their Accademia as early as in 1625.[295] All these elements suggest that the drawing of asbestos at Windsor, with its focus on the linty appearance of the

[292] The argumentation of Cesi was laid out in its tabula 8, spreading over 5 pages of his volume. On the first page Cesi rapidly addressed the idea of paper as derived from the human process of macerating rags but on the second page, that he dedicated entirely to paper, he inserted paper as an artefact derived from plants. Federico Cesi, "Phytosophicarum tabularum", p. 923.

[293] Luigi Guerrini, "Alle origini del concetto di vita in Federico Cesi tra le 'Tabulae phytosophicae' e l''Apiarium'" in Antonio Graniti (ed. by), *Federico Cesi: Un Principe Naturalista*. *Atti dei Convegni Lincei* 225 (Roma: Bardi Editore, 2006), pp. 439-462, p. 445.

[294] D. Freedberg, *The eye of the Lynx*, p. 33.

[295] Anna Rita Romani, "Francis Bacon e il Carteggio Puteano", in Francesco Solinas (ed. by) *Cassiano dal Pozzo: Atti del Seminario internazionale di studi*, (Roma: De Luca, 1989), pp. 31-36, pp. 31, 34-35.

support, could be read as a significant representation within the interest in fibres that absorbed the observations of Cassiano.

2.3 Cassiano's drawing of asbestos

In the previous chapter we have considered how the use of a fuzzy support in Cassiano's drawing of asbestos perceptively conveyed the fibrous appearance of the mineral. I am now going to consider how such a distinctive paper was also remarkably significant by virtue of what Cassiano was gathering from his observations. This can be inferred from the analysis of the subject of that drawing itself (fig. 2.11a). Although the drawing is well-known and has been repeatedly reproduced, historiography has considered its subject only to some extent, mostly providing a bare description of the objects there represented.[296] The drawing, however, was clearly not an ordinary depiction. It was apparently conceived in the form of an analytical study articulated on a visual grounding, rather than verbalised and, despite its meaning may not be easy to establish with certainty, it is worth being considered here in detail.

Before examining what was represented in the drawing, it will be necessary to remember that asbestos was a major subject of interest among naturalists at the time. Ferrante Imperato (1525 ca. 1615 ca.), the famous apothecary from Naples and collector of *naturalia*, had included an emblematic plate of it in his *Dell'Historia Naturale* (1599) (fig. 3.4).[297] That picture illustrated a demonstration of the renowned incombustible property of asbestos that naturalists interrogated. The phenomenon, indeed, inspired collectors like Ferrante to occasionally repeat the experiment by exposing artefacts made from it to fire and observing them remaining intact.[298] Although the depiction of an asbestos rope in the drawing from the Paper Museum may recall a detail of Imperato's plate, Cassiano apparently wanted something very different to be represented. Instead of illustrating the incombustible quality of asbestos, his drawing was all about its fibres and the property of that mineral being converted, by virtue of them, into different artefacts. Those fibres, indeed, were meticulously depicted as they determined, in a gradual sequence of refinement, the different degrees of processing asbestos. Hence, while the first object represents the natural state of the mineral, at the top of the sheet (fig. 3.5a), the

[296] The main research on the asbestos drawing has been done by Caterina Napoleone in: Henrietta McBurney, Ian Rolfe, Caterina Napoleone, Paula Findlen (eds.), *Birds, other Animals and Natural Curiosities. The Paper Museum of Cassiano dal Pozzo* vol. 2, (London: Royal Collection Trust, 2017), pp. 611-612, 622-624, 847-849.
[297] Ferrante Imperato, *Dell'Historia Naturale di Ferrante Imperato Napoletano*, (Napoli, 1599) p. 679.
[298] On the recurrent experiments on the incombustibility of asbestos see: Paula Findlen, *Possessing Nature*, pp. 225-226. More recently: Valentina Pugliano, "Natural History in the Apothecary's Shop" in Helen Ann Curry, Nicholas Jardine, James A. Secord, and Emma Spary, (eds.), *Worlds of Natural History* (Cambridge University Press, 2018), pp. 44-60, pp. 57-8.

other items show the ways in which asbestos fibres give form to different artefacts. The first among them depicts the fibres simply twisted into a partially unwound rope (fig. 3.5b), while the following one shows how spun fibres can be knitted to form a cap (fig. 3.5c). Another figure pertaining to a different sheet, likely cut off from the same blue paper, represents the woven state of asbestos in a fragment of a rough cloth (fig. 3.5d).[299] Finally, the small item in the lowest part of the drawing has been more difficult to identify (fig. 3.5e). The depiction of this small item has been variably indicated as a "sheet", a "finely woven sheet" or possibly a piece of paper.[300] However, as I will expose with clear evidence in the following chapter, that object certainly represented a fragment of asbestos paper, the first one ever made. The study drawing, therefore, was aimed at contemplating what asbestos fibres were about, and we may reasonably wonder what Cassiano assumed from it. The subject could be read in two different ways: one concerning the general properties of fibrous materials, and the other one addressing the specificity of asbestos fibres.

The progression represented in Cassiano's drawing, from the primary state of the fibrous rock to its different applications, apparently echoed Cesi's analytical method. The sequence from the natural form into the artefactual one, indeed, adopted the same categorization contemplated in the *Tabulae Phytosophicae* with regard to the conversion of plants into textiles and, from them, into paper. As such, therefore, the drawing might have concerned not just asbestos but also the properties of fibrous materials in more general terms. In particular, it could have been an attempt to speculate on the ontology of fibres as the minimal building units of some substances, being those artefacts that were the mere temporal phases in the existence of that same chunk of matter.[301] The sample of asbestos paper, being the last and extreme stage of transformation in which fibres still retained the same property of the mineral in its primary form, might have provided some indication about the distinctive property of fibres in creating diverse forms of entanglement: a direction in line with Bacon's reflections.

Concerning the specific study of asbestos, and following the common cognition about the mineral's oddity, Cassiano might reasonably also have been investigating the obscure reasons for the singularity of that matter. He might have contemplated what made asbestos as

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[299] A picture of this fragment plausibly cut out from the original drawing is published in: Francesco Solinas, *I segreti di un collezionista: Le straordinarie collezioni di Cassiano dal Pozzo* (Roma: Edizioni De Luca, 2000), p. 165.

[300] Caterina Napoleone, who studied the drawing in details did not provide a clear definition of the fragment depicted. This has been generically defined as a "sheet" or a "finely woven sheet", possibly seen in contrast with the coarse weave in the catalogue 256, p. 624. More recently Clare Browne, writing on asbestos textiles, has indicated that the sample might represent a piece of paper, but no evidence was adduced. Clare Browne, "Salamander's Wool: The Historical Evidence for Textiles Woven with Asbestos Fibre", *Textile History*, vol. 34, 2003, I. pp. 64-73, p. 70.

[301] That concept was openly articulated in 1655 by Hobbes. Maarten Franssen, Peter Kroes, Thomas Reydon, Pieter Vermaas, "Introduction: The ontology of technical artefacts", in M. Franssen, P. Kroes, T. Reydon, P. Vermaas, (ed. by), *Artefact Kinds: Ontology and the Human-Made World*, (Cham: Springer, 2014), p. 5.

distinctive as a stone but also similar to other materials, once he had considered the properties of its fibres. The objects that Cassiano chose to represent were possibly suggesting that asbestos' fibres, which were supposed to be of mineral nature, bore not much difference from those of a vegetal or animal origin. Vegetal filaments, as well as some animal wools, could be twisted to form a twine or a thread to weave or knit and, in turn, be eventually used to make paper. Fibres, which allowed asbestos to be processed in exactly the same way, might have suggested that such a mineral intrinsically shared something in common with those organic substances.

However we interpret Cassiano's study of asbestos, it seems that the observation of those objects, which prompted their representation, had to consist of an extraordinary thought-provoking process. It is possible that Cassiano conceived of the tableau whilst wondering about the appearance and ontology of asbestos and its fibres: a complexity of questions conveyed through the visualization of those artefacts like in a rebus. The lack of any written evidence unfortunately hinders us from knowing precisely the actual meaning of the drawing and in conclusion it remains an obscure representation to some extent. Nonetheless, the picture undeniably indicates that Cassiano, following Cesi's steps and consistent with Bacon's view, was concurrently looking at paper fibres as a form of matter with an open mind. For Bacon, as well as for Cesi and Cassiano, the observation of paper had a primary role in encouraging the reflection that was leading to the loosening of the restrictive boundary between nature and artifice. In conclusion, the views expressed by both Bacon and the Linceans, as driven by their genuine observation of paper's fibrous matter, were not without controversial implications. By approaching the inconsistency of a clear distinction between artifice and nature, their contemplation of paper was implicitly contributing to a more general overturn of an Aristotelian principle which, as we are going to see, also diverged from the vision of the theological doctrine.[302]

2.4 The shift: paper from artefact to material

The impact of Bacon's vision and the persuasive strength of his ideas have been generally recognised as substantial. However, whereas historiography has debated much on the role of the philosopher's thought for the industrial development, a different aspect of his influence

[302] Lorraine Daston and Katharine Park, *Wonders and the Order of Nature 1150-1750* (New York: Zone Book, 1998), pp. 290-301. and Dennis De Chene, "Forms of Art in Jesuit Aristotelism (With a Coda on Descartes)" in Bernadette Bensaude-Vincent and William R. Newman (eds.), *The Artificial and the Natural: An Evolving Polarity*, (London, MIT Press, 2007), pp. 135- 136.

apparently has been neglected.[303] For what concerns my own research, I will trace how his words on fibres were received. It is possible, indeed, to identify a consequence of Bacon's approach by following how his observations of the material of paper did not remain ignored, but rather contributed in driving the interest in the nature of matter. Such a focus, in particular, concerned the nature of fibres and developed in congruence with the increasing use of microscopes among naturalists.

Bacon's passages on paper and his more general discourse on fibres were largely embraced by the Italian scientist and philosopher Francesco Lana Terzi (1631-1687). The position of Lana Terzi is particularly relevant not only due to his interest in paper's matter but also because his view, as a Jesuit, reflects a persistent challenge prompted by the scientific observation of paper. His reflections on matter, addressed from the point of view of his congregation's dogmatic belief, brought him to approach the edges of religious doctrine. In his *Magisterium naturæ et artis* (1684), Lana Terzi openly adopted Bacon's inductive reasoning and extended some ideas from the *Novum Organum* with evidence derived from his own direct examinations.[304] The volume addressed the principles of natural philosophy and, in the second tome, he focused on the fundament of the cohesive force of matter. Taking Bacon's proposition almost literally, Lana Terzi thus engaged in a comparative analysis of the reason behind the distinctive resistance to partition among many different substances.[305] Fibres were crucial to that analysis since Lana Terzi postulated that every body, whether animal, vegetal, mineral, and even glass or ice, is merely composed of *filamina*, *fibrulas* or, in other words, fibres.[306] On such a proposition, paper assumed a particular significance, being a benchmark for comparison. His investigation, indeed, indiscriminately considered natural and artificial substances. Among the latter ones, coherently with Bacon, he acknowledged that paper was the one most similar to natural matter.[307] Nonetheless, Lana Terzi's position diverged from Bacon when addressing the analogy between paper's structure and that of natural meshes of fibres. In particular, while Bacon assimilated paper to skin or any animal or vegetal membrane, Lana Terzi formed an analogy of paper with metals. In his view, metals had to share with paper a similar radial distribution within its imperceptible entanglement of fibres, which bestowed those materials with an analogous

[303] That aspect had first been explored by Benjamin Farrington, *Francis Bacon: Philosopher of Industrial Science*, (London: Lawrence and Wishart, 1951). For a more recent view on Bacon's role in British industrialization see: William J. Ashworth, "The Intersection of Industry and the State in Eighteenth Century Britain", *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation* (Amsterdam: Edita KNAW, 2007), pp. 349-377.
[304] Francesco Lana Terzi, *Magisterium naturæ et artis* (Brescia, 1684-1692).
[305] This section refers to the liber XI of Lana Terzi's second tome on the cohesive force of bodies and respective restraints "De adhaerentia partium ed invicem in eodem corpore, et de resistentia discontinuationis", Francesco Lana Terzi, *Magisterium naturæ et artis, Tomus II* (Brescia, 1686).
[306] F. Lana Terzi, *Magisterium naturæ et artis*, pp. 492-496.
[307] F. Lana Terzi, *Magisterium naturæ et artis*, p. 487, XIV.

intrinsic plasticity.[308] However, it is arguable whether, as a Jesuit, Lana Terzi considered Bacon's comparison of the manmade matter of paper with the living one, such as skin or membrane, as untenable.

Considering nature and artifice in the same way, especially placing them at the same level, was certainly not an easy statement to support from a theological point of view. Lana Terzi, indeed, resolved beforehand any possible discordance with religious doctrine by clarifying that all bodies, as disposed by God and regardless of their nature, have a breaking point at which matter divides, the substance of Christ's body from the Eucharistic bread being the sole exception.[309] It had to be his own position as a religious scientist that led him to address the comparison between the structural form of man-made paper and animal skin with some necessary caution. He felt the urgency to dispel any ambiguity by putting paper and parchment under the microscope and considering their textures in terms of their respective arrangements of fibres.[310] In particular, the fibres of parchment appeared to him "less confused and disordered" than those of paper and, although he recognised that the surface of parchment was actually very similar in texture to coarse paper, he promptly noticed that parchment's particles appeared more dense, which caused the superiority of its resistance to tearing. In other words, Lana Terzi remarked on the fortuitous chaos of paper's fibres as something that could not be compared with the deliberated purposefulness associated with animal skin. His argument thus suggests the underlying ambiguity of a position in-between the embracement of religious doctrine and the genuine observations of a scientist. Nonetheless, although his personal background apparently impinged upon his investigation, by looking at the constitution and structure of paper's matter, he had de facto sidestepped its artefactual nature and was rather looking at it for its being simply a material. While doing so the boundary between artificial and natural had inevitably lessened its relevance.

The consequences of looking at paper as we have seen so far could not have been more significant. After having observed paper's derivation from plants and scrutinised its composition as an entanglement of fibres, it was inevitable that at any similar agglomerate of vegetable origin found in nature would be identified as paper. This is precisely what happened whenever naturalists bluntly indicated as "paper" something occurring in nature with no relation to human activity. In 1763 a thin and uniform coat of desiccated vegetal matter was found along the surroundings of a marsh in Cortona, Tuscany, after a flooding. That deposit immediately caught the attention of local naturalists, who named that substance "natural paper of Cortona" and

[308] F. Lana Terzi, *Magisterium naturæ et artis*, p. 494.
[309] F. Lana Terzi, *Magisterium naturæ et artis*, p. 491.
[310] F. Lana Terzi, *Magisterium naturæ et artis*, p. 494.

invited John Strange, a member of the Royal Society, to investigate the singular phenomenon about which he reported in detail to his London fellows.[311] The name of paper, therefore, was significantly given to the outcome of an accidental natural process. However, the earlier case of the French entomologist René-Antoine Ferchault de Réaumur (1683-1757) is maybe better known. [312] In 1719 the entomologist presented to the Académie Royale his observations on how certain breeds of wasps processed wood and, by reducing it into a pulp of fibres, were remarkably able to produce diverse qualities of "paper" and "cardboard" for building their nests.[313] Being earlier indicated by the paper historian Dard Hunter, the case is generally considered a decisive moment in the history of paper. [314] As alluded to by Réaumur himself, this was the first time someone mentioned the possibility of making paper by processing wood, avoiding the need to use rags. However, as I tried to unfold in my research, such a turning point was more than a sudden intuition. Réaumur's acumen was rather the consequence of a long process of obtaining knowledge concerning paper, its nature and the matter of fibres. That understanding had started at least a century earlier and grew directly from observations as engaged in by generations of naturalists. Direct and accurate observation was nothing less than the same attitude that led the French entomologist to tirelessly scrutinise any of his own subjects of study, "seeing again and again", as has been stated.[315] Free from the theoretical boundary between nature and artifice, which still echoed but had lost its relevance in Lana Terzi's writing, Réaumur was able to see an intrinsic equivalence between the material of wasp nests and that made by papermakers. It was through that correspondence that the human process of papermaking from rags and the one performed by wasps from wood could be seen alongside and in reciprocity with one another, potentially offering inspiration for the former to be changed.

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311 Lodovico Coltellini, "Lettera Scritta il di' 7 Agosto 1763 dal Sig. Coltellini al Sig. Dottore Annibale Bastiani", *Novelle Letterarie pubblicate in Firenze*, XXIV, 1763. pp. 598-602. John Strange, *Lettera sopra l'Origine della Carta Naturale di Cortona*, (Pisa, 1764). John Strange, "An Account of an Essay on the Origin of a Natural Paper, found near the City of Cortona in Tuscany, 16 February 1769", *Philosophical Transactions of the Royal Society of London*, Vol. 59, (London, 1769), pp. 50-56.

312 René-Antoine Ferchault de Réaumur, "Histoire des Guêpes, 15 Novembre 1719", *Histoire de l'Académie Royale des Sciences*, (Paris, 1721).

313 R. Réaumur, "Histoire des Guêpes", pp. 230-277.

314 Dard Hunter, *Papermaking: The History and Technique of an Ancient Craft*, (1943), pp. 233-235.

315 On the experiential observation of Réaumur's practice see: Mary Terrall, *Catching Nature in the Act: Réaumur and the Practice of Natural History in Eighteenth Century*, (Chicago: University of Chicago Press, 2014).

3. The heuristic model of paper

It is easy to read the events considered to this point as an inexorable advancement. Seeing paper according to its properties rather than what it is made out of, means that its material could be redesigned. This was indeed what happened in the 19th century, as prompted by the perspective of a potentially unlimited source of wood against the unsustainable use of rags which were in short supply. With hindsight, paper historians have indeed indicated Réaumur's observations as an early move that pointed in that direction. Nonetheless, that perspective only considers the contribution of the French entomologist according to a narrative framing the development of paper as a commodity. In doing so, it hinders the broader understanding of how paper was constantly and widely affecting European culture and especially influencing its scientific development. However, the scientific observation of paper, to which Réaumur's case pertains, represented a more significant phenomenon than the conventional narrative of paper history recognises. While in the previous chapter we have seen that the use of paper led scientists to embrace it as a technology of visualization, we are now going to explore how the scientific observation of paper's substance brought them to see it as a heuristic model for the organic matter of fibres to be examined. As the scrutiny of paper and its fibres provided naturalists with a sample for the investigation of matter's composition and structure, the observation of paper's action intersected with more general and crucial questions concerning the functionalities of living matter. Therefore, with the rising knowledge of fibres and by relating it to the contemporary theories of matter, paper went on to influence the early empirical exploration of human physiology.

3.1 The grain of matter and the rising age of fibres

Since the beginning of the 17th century, the rediscovery of the theory of atomism formulated by the ancient Greek philosopher Democritus (460 ca.- 370 ca. BC), long discredited over Aristotle's conflicting model, made concepts such as corpuscles, particles, and atoms central to the scientific debate.[316] Paradoxically, in the blooming age of empiricism, such theories based on small indiscernible particles were challenging, as their evidence could not be supported by visible proofs. Under the microscope, direct observation only enabled scientists to acknowledge that the grain of matter was not homogeneous and that even the most polished

[316] Voir Christoph Lüthy, "The Four Conflated Democriti in the Early Seventeenth Century Alchemy and Medicine", in Michel Bougard (ed.), *Alchemy, Chemistry and Pharmacy*, (Turnhout: Brepols, 2002), pp. 29-49, p. 32-33.

surface showed some sort of texture.[317] Given the unfeasibility of experimental verification, atomism necessarily embraced the speculative direction.[318] At the same time, other lines of investigation were apparently taking a different approach to examining matter, driven by a more direct observation of substances' constitution. In that context, fibres represented a compelling enquiry. The relevance of their theorisation remains a neglected theme in the current literature, having been raised only recently and primarily in relation to anatomy.[319] Nevertheless, it has been argued, fibres were destined to determine the new vision in the medical field of the 18th century.[320]

Already observed by earlier anatomists, fibres gradually assumed relevance as the fundament in the exploration of the function-structure complexes of organic bodies.[321] In line with the humoral doctrine, Andreas Vesalius (1514-1564) had illustrated in an enlightening picture from his *De humani corporis fabrica* (1543) the theorization of fibres as a combination of transverse, oblique and straight arrangements (fig. 3.6).[322] Such an interweaving was at the core of the organic matter's activity, which supplied the body with the necessary nourishment and expelled excretions.[323]

In the 17th century, the investigation of fibres relied on some persuasive points. Fibres could certainly be inspected under the microscope but could also be observed by the naked eye and even experienced first-hand with some materials. The conflicting influence of the microscope in scientific progression has been addressed by Catherine Wilson, who acknowledged the profound "sense of dislocation" generated by magnification.[324] Under those circumstances, the observation of paper's fibres might have bridged the speculative and experimental visions, easing the unintelligibility of the image under the microscope with direct experience. Paper as an artefact, along with textiles, provided an operative example of how the

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317 Catherine Wilson, *The Invisible World: Early Modern Philosophy and the Invention of Microscope*, (Princeton: Princeton University Press, 1995), p. 58.

318 Christoph Meinel, "Early Seventeenth-Century Atomism: Theory, Epistemology, and the Insufficiency of Experiment", *Isis: A Journal of the History of Science*, 79, 1988, pp. 68-103, p. 84.

319 After the work of Alexander Berg, in 1942 (Alexander Berg, "Die Lehre von der Faser als Form- und Funktionselement des Organismus", *Virchows Archiv für Physiologische Anatomie und Physiologie und für klinische Medizin*, Vol.309 (1942), pp 333–460), the subject of the advancement in the scientific knowledge of fibres has only recently been studied by Tobias Cheung and Hisao Ishizuka.

320 Hisao Ishizuka, "'Fibre Body': The Concept of Fibre in Eighteenth-Century Medicine, c.1700–c.1740", *Medical History*, n. 56 (October 2012), pp. 562–584, pp 562-3.

321 Tobias Cheung, "Omnis Fibra ex Fibra: Fibrae Œconomies in Bonnet's and Diderot's Models of Organic Order" in Tobias Cheung (ed. by), *Transitions and Borders between Animals, Humans and Machines 1600-1800* (Leiden: Brill, 2010), pp. 66-104, p. 66.

322 Andreas Vesalius, *De humani corporis fabrica* (Basel, 1543), p. 437.

323 For a reading of Vesalius' representation of fibres see: John B. de C. M. Saunders, Charles O'Malley, *The Illustrations from the Works of Andreas Vesalius of Brussels,* (Cleveland: World Publishing Co. 1950), p. 138. And Tobias Cheung, "Omnis Fibra ex Fibra", pp. 71-74.

324 On the "sense of dislocation" and the early use of microscopes in reply to Gaston Bachelard's idea of the epistemological obstacle see: Catherine Wilson, *The invisible World: Early Modern Philosophy and the Invention of the Microscope* (Oxford: Princeton University Press, 1995), pp. 251-256.

different structures of fibres could be artificially determined and, therefore, how they were actually working. However, as we have seen with Lana Terzi, while paper was early identified as an exemplary matter, it appears that the casual arrangement of its fibres had to raise some concern, as its chaotic organization could hardly be equated with the seemingly purposeful arrangement of a product of nature. It has been observed that many naturalists who studied the minute texture of organic matter in the late 17th century adopted a rich set of metaphors from the textile vocabulary in order to convey the sense of what they saw.[325]

The case of Nehemiah Grew (1641-1712), as studied by Hisao Ishizuka, represents a significant case. The English botanist thoroughly embraced the metaphors of textiles to support his observations of the anatomy of plants, comparing their configurations to needlework and embroideries also through fascinating illustrations (fig. 3.7).[326]. Moreover, by associating the vegetal with the animal kingdom, he aimed at expressing the beauty and the order of fibre structures in those respective spheres of life. Grew's vision was determined by the urgency to decode organic matter from the point of view of his role as a clergyman. In doing so, as Ishizuka clarifies, he was also searching for the divine prodigy expressed in those minute and sublime structures of nature.[327] It may appear obvious, therefore, why the confused and accidental form of its paper fibre mesh might have seemed inappropriate, with respect to textiles, in comparing the natural configuration of the organic fibres observed under the microscope. Therefore, the textile metaphor was successfully embraced, since the arrangement of paper's fibres did not bear comparison with the flawless work of nature. Nevertheless, the analogy between paper and organic matter was not entirely discarded. Instead of being adopted with regard to the microstructures of organic matter, that analogy was rather embraced and reinforced when exploring its operative function. As we are going to see, the fibrous material of paper actively stimulated the reflections of anatomists when they turned from looking at the structures of matter to fathoming their operative function. In that view, paper was embraced as a heuristic means, providing a preliminary model of functioning for the study of the brain and the physiological processes of the glands.

[325] Hisao Ishizuka, "Visualizing the fibre-woven body: Nehemiah Grew's Plant Anatomy and The Emergence of the Fibre Body" in Brian Muñoz, Matthew Landers (eds.) *Anatomy and the Organization of Knowledge, 1500–1850*, (London: Pickering & Chatto 2012), pp. 113-128, p. 116.
[326] H. Ishizuka, "Visualizing the fibre-woven body", p. 120.
[327] H. Ishizuka, "Visualizing the fibre-woven body", p. 124.

3.2 Paper and the matter of the brain: From substance to function

Since Pliny's most influential work, we have seen how paper, as a physical support to written texts, had been constantly considered crucial for the transmission of knowledge. As exposed in the previous chapter, over the course of time the instrumental adoption of paper among the learned started to present its problems, with the consequent difficulty for scholars and early scientists in accessing the increasing amount of knowledge stored in their books. As argued by Richard Yeo, the conceptualised relationship between information storage on paper and human memory has its own history. [328] Books, notes and commonplace-books among early modern scholars developed from simple tools to improve and sustain memory into systems capable of externally storing and organising information, eventually assisting intellectual operations. The adoption of paper as an external alternative aid to the internal storage of information operated by memory is fascinating and cannot be eluded. Thanks to its extraordinary receptiveness to ink and the versatility of its substance of fibres, paper successfully mastered this alternative function to human memory. Yeo, indeed, reported that Descartes (1596-1650), when asked about the weakness of memory, replied that written notes would easily support somebody who struggles to remember.[329]

Descartes implied that the two acts of note taking and mentally retaining information could be considered as interchangeable operations. Later, philosophers and early physiologists exploring the mechanics of memory's functioning had to find some pertinence in the idea of a brain made of a receptive matter endowed with the quality of sensitive pliancy. That model was significantly investigated by Descartes himself in *L'Homme*, published in 1662, although written 30 years earlier. In the model defined by Descartes, nerves received and transmitted visual stimuli projected within the eye through their canals, which contained small fibres, along with "animal spirits". The core of perception was located within a thick mesh of pressed fibres, which was assumed to form the brain's matter: the ultimate site of human discernment and memory. The process of seeing materialized among the brain's fibres and their interstices (the pores), in which the spirits operated their mediation between the physical body and the conceiving soul.[330] Those spirits, flowing incessantly, expanded or constricted the pores, continuously bending and rearranging the fibres. In turn, those fibres were considered to be actively responsive as if made of wax or lead, thus enabling the spirits to impress traces and figures upon

[328] Richard Yeo, "Between Memory and Paperbooks: Baconianism and the Natural History in Seventeenth Century England." *History of Science*, 45, 2007, pp. 1-46.
[329] Yeo, "Between Memory and Paperbooks", p. 3.
[330] For an explanation of the process see: John Sutton, *Philosophy and Memory Traces: Descartes to Connectionism*, (Cambridge, Cambridge University Press, 1998), pp. 102-106.

them, so that patterns may persist after the action of the perceived object had ceased.[331] Descartes compared memory to the folds on paper that effortlessly retain their shape, even in the absence of external forces. However, he never openly elaborated upon the analogy between the brain's matter and paper. Rather, he adopted the textile metaphor when defining the substance of the brain like a "*rezeuil ou lassis*": both terms used in French for lace nets. Nevertheless, in the same sentence, he recalled the manufacture of paper when specifying that such a net of fibres appeared "compact and pressed", "*épais et pressé*", completing his model with a close analogy with the actual result of papermakers' operations.

The resemblance of brain's sensitive matter with paper, although only vaguely addressed by Descartes, was though embraced by one of the French philosopher's most zealous advocates, Theodor Craanen (1620-1690). In his work, which embraced and expanded the Cartesian model of human physiology, Craanen came back to the idea of paper folds to convey the persistence of memory, but such an analogy with paper was not limited to it.[332] He directly defined the substance of brain matter as a "*contextum fibrosum*" in which fibres appear reciprocally entangled, similarly to what is visible in textiles, paper and any vegetal membrane.[333] Finally, when discussing imagination, he formulated a model in which the analogy with paper was embraced even more openly. Craanen explained how some images materialised in the form of "impressions" within the brain by the irradiance of spirits: this happened when the fibres were bent, like they are in paper, and when the interstitial pores were enlarged, as it is also visible when a needle pricks a paper sheet and leaves a pinhole.[334] Likewise, imagination was conceived of as a semantic system of images and signs generated by the spirits out of the folds of fibres and enlarged pores. The physician even envisioned the outcome of those processes in two engravings to clarify how the texture of brain's matter appeared punched with emblematic forms such as the *fleur de lys*, which inevitably recalls one of the most common figures among paper's watermarks (fig. 3.8).

With his cohort of adherents and detractors, and well before the neuronal network was discovered, Descartes' theory became a captivating model to explain the responsiveness of the human brain and how, through its fibres, it was enabled to store and recall information, even developing imagination. From the way paper was used as an analogy, or we may say as a heuristic tool to articulate the brain's model, it is clear that the cognition of such a material was

[331] René Descartes, *Treatise of Man*, Trans. by Thomas Steele Hall, (Cambridge MA, Harvard University Press, 1972), pp. 77-86.
[332] Theodor Craanen, *Tractatus physico-medicus de homine, in quo status ejus tam naturalis*, (Leiden, 1689), p. 586.
[333] "Diximus cerebrum esse merum contextum fibrosum, ubi fibrae aliae aliis inter texantur, non aliter ac hoc videmus in linteis, pannis, chartis, plantis, arboribus, membranis, & c." T. Craanen, *Tractatus physico-medicus,* p. 584
[334] T. Craanen, *Tractatus physico-medicus,* p. 576.

in constant development. Paper was not denoted by its raw material anymore, and not even only by its structure: it was rather defined by its operative qualities as a responsive material of fibres.

3.3 Paper filters and physiology

As a material that is essentially formed in and through water, paper was endowed with properties related to fluids, such as imbibing, retaining ink and filtering. The apothecary practices between the 17th and 18th centuries were accustomed to experiencing paper as the most ordinary filtering tool to clarify solutions. A 1728 Venetian volume of pharmacology prescribed the use of paper filters for cleansing each one of the preparations enlisted.[335] Such a practice was certainly very common and widespread at that time, but not new. In 1688 Robert Boyle (1627-1691) had indicated the same use of a cap paper filter for clearing a solution from one of his precipitates and he certainly was not the first one to use paper in that way.[336] Although such a practice was determined by the simple necessity to refine solutions, another similar application of paper was well known among chemists and physicians. That referred to a specific experiment concerning the use of blotting paper, or any other low-quality type such as cap paper, to separate water and oil mixtures by individually extracting each component. As stated by many, when moistened with water, paper only lets the water pass through, preventing the oil trickling down. Vice versa, paper preventively soaked with oil had the opposite effect.

The experiment of separating oil and water through paper, which assumed an intrinsic selective property of that porous matter of fibres, had to appear enlightening to the anatomists who were early debating about physiology in the 18th century. It should not come as a surprise, therefore, that paper provided a reasonable model for some physiological functions in the contemporary vascular theory concerning the control and function of bodily fluids. The parallel between filters and physiological functions already had a long history. The definition of the ancient Greek physician Galen (130-210) of the porous membrane of skin as a straining sieve, "cribellum", had long been an effective image to describe the way the body functioned to selectively expel only its excremental products.[337] Even when Galen's humoral theory started to

[335] Giovanni Battista Capello, *Lessico Farmaceutico-Chimico*, (Venezia, 1728).
[336] Robert Boyle, *Some receipts of medicines for the most part parable and simple sent to a friend in America*, (London, 1688), p. 24. An earlier use of paper for the filtration of chemicals is described in: Paolo Boccone, *Osservazioni naturali ove si contengono materie medico-fisiche, e di botanica*, (Bologna, 1684), p. 282.
[337] "Et creata est una perforata ut cribellum ad hoc, ut per ipsam fiat respiratio vaporosarum substantiarum seu superfluitatum interiorum membrorum, ex quibus in pluribus partibus studet natura pilos multiplicare, ut eos obijciat rebus nocivis et permutativis, et ut sint tutamentum et defensio nobilis membri, in cuius regimine solicita est nimium natura". Giulio Marziano Rota, *Tomus Octavus in quo insunt libri Galeno ascripti*. (Basileae, 1542), p. 168 D.

decline, such a powerful image persisted. At the beginning of the 18th century, Herman Boerhaave (1668-1738) theorised his iatromechanic model of human physiology as a system of "sieves, strains and pipes".[338] In the specific case of the kidney's function, as it had been studied, the tradition of the complex action of blood filtering relied on a continuity that was gradually reformulated from Aristotle and Galen to Marcello Malpighi (1628-1694), passing through Mondino de' Liuzzi, Vesalius and Giovanni Borrelli.[339] After the observation of fibrous structures, as studied by Malpighi through the microscope, the filtering function of paper became crucial to the more general enquiry into the processes of glands. Irish physician Bernard Connor (1666-1698), who backed at an early stage the theory of fibres in England and supported the observations of Malpighi himself, illustrated his model of glands in a section of his *Evangelium Medici* (1697). To illustrate the physiological process operated by glands, he essentially reported the experiment of paper filters to separate oil and water.[340] According to his view, sweat, urine and bile, as well as any other secretion, were all extracted from blood by virtue of the different type of glands within the body. These mainly functioned in the same way as paper separated oily liquids from watery ones. It is hard to track the source of such a persuasive analogy, but certainly several other authors mentioned that similitude between organic physiology and the selective action of paper.[341]

The analogy of paper to explain physiological processes had to be so widely accepted among 17th century physicians that the philosopher and scientist Martino Poli (1662-1714) felt compelled to offer some clarity. In his *Il Trionfo degli Acidi* (1706) Poli warned the community of scholars about the predominant theories diffused among many of his contemporaries.[342] He firmly discredited Corpuscolarism, Iatromechanism and especially Descartes for having inspired the rise of what he called "*medicina cribratoria*": the medical principle that conceived the body

[338] Charles T. Wolfe, "Forms of Materialist Embodiment", in Brian Muñoz, Matthew Landers (eds.) *Anatomy and the organization of knowledge, 1500-1850*, (London: Pickering & Chatto 2012), pp. 129-144, p. 133.
[339] Michael R. McVaugh, "The disappearance of attraction from the kidney", in Manfred Horstmanshoff (ed. by) *Blood sweat and tears. The Changing Concepts of Physiology from Antiquity into Early Modern Europe*, (Leiden: Brill, 2012), pp. 103-137, pp. 110-116.
[340] "Hoc illustrare facile est experimento vulgari cum oleo, aqua & charta chymicorum empoertica seu bibula celebrato. Oleum Aquae limpidae nullo sale aculeatae affundatur, & spatula, quantum potest, agitatum eidem intime admisceatur. Si animus est aquam ab oleo separare, sumatur charta in aquam prius immersa, & in hanc chartam vasi impositam oleum & aqua affundantur; tota aqua per chartæ porulos aqueis particulis jam repletos, relicto pone oleo, tranfibit. Si vero quis vellet oleum prius ab aqua fecernere, charta in oleum immergatur, & nihil praeter oleum per poros illius oleo prius gravidos percolari poterit. Eodem modo concipi facile potest quod omnes corporis nostri glandulae." Bernard Connor, *Evangelium Medici seu Medicina Mystica*, (Amsterdam, 1692), pp. 173-174.
[341] Some years earlier, in 1683, Jan Muys mentioned the same experiment of paper filters with water and oil to explain the reason for a failed expulsion of an acid component from the blood in the case of a tumor in the eye. Jan Muys, *Praxis chirurgica rationalis*, (Leiden, 1683), p. 9. The same analogy was reported by others: Elias Rudolph Camerarius, Ernest Joseph Albeckh, *Dissertatio medica inauguralis, de glandulis p.n. patulis* (Tübingen, 1689), p. 10 and Friedrich Hoffman, *Opuscula medico-practica seu dissertationes selectiores*, (Halle, 1736), p. 551.
[342] Martino Poli, *Il Trionfo degli acidi vendicati dalle calunnie di molti moderni*, (Roma, 1706).

as a system of filtering sieves, or *cribra*.[343] Poli's writing was a manifest of dissent that debunked the most common diagnoses, observing that "everywhere you can hear about clogs of filters and mutations of texture".[344] His volume was ultimately targeting the most recent theory of fibres by the physician Giorgio Baglivi (1668-1707), who had identified in those filaments the core principle of life's motion.[345] Although Poli's volume was a philosophical treatise, his work addressed the current medical theory of physiology by discrediting the supposed proofs with his own evidence. A main assumption of Poli's argument, aimed at disproving the mainstream principles, was based on the inconsistency of the paper filters' principle. Poli examined their operative fundament with different solutions and, by discrediting the experiment of the separation of oil and water through paper, he concluded that the inert matter of a paper filter was by no means able to separate, but only dribbled passively, "*passivo modo*", stressing that concept with the use of the italic type.[346]

The vision of Poli represents a clear transition. In his view, chemical processes, rather than mechanic principles, were at the foundation of physiology. His model, indeed, was based on distillation as opposed to simple filtration. Therefore, acknowledging the passive action of paper filters, far from being a moot point, rather was a crucial premise. It established the incontrovertible inertia of paper's fibres and moved against the undercurrent of opinion that those components had a role in the living principle of organic matter itself. The heuristic model of paper filters had apparently exhausted its purpose and a new, more advanced paradigm had become necessary to represent the complexity of nature that was gradually emerging. In his criticism, Poli's objection exposes the role of a humble matter as that of paper in the human attempt to fathom how nature works. While the association between physiology and paper was made obsolete by Poli's evidence, the study of fibres persisted as a legacy of the earliest observations of paper's matter, developing further during the 18th century and laying the foundation for the theorisation of the irritability of fibres and sensory perception.[347]

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[343] M. Poli, *Il Trionfo degli acidi,* preface, no page.

[344] "nella spiegazione delli morbi, altra voce non si sente che di ostruzzione di filtri, di mutazione di figure, e di equilibrio, di coagulazione ne i fluidi". M. Poli, *Il Trionfo degli acidi,* preface, no page.

[345] In Poli's volume, Baglivi was simply mentioned as a "modern author" although he dedicated to his own work a long section of comments and objections (pp. 142-186). On the controversial theory of Baglivi see: Mirko Grmek, "Il De fibra motrice et morbosa di Giorgio Baglivi", *Medicina nei Secoli*, 12, 2000, pp. 19-27.

[346] M. Poli, *Il Trionfo degli Acidi*, p. 105.

[347] On the continuity between the iatromechanical model to the vitalistic theory of the sensitive body in relation to fibres from the focus on muscles to nerves see: Hisao Ishizuka, "The Elasticity of the Animal Fibre: Movement and Life in Enlightenment Medicine", *History of Science* vol. 44 (146) 2006, pp. 435-450.

Chapter IV

Making paper: The material knowledge of scientists and artisans through the process of papermaking

Introduction

As we have seen in the first chapter, the specialised literature of paper history has always acknowledged the problem of rags shortage, often stressing how paper manufacture, being contingent on such a raw material, encountered recurring difficulties in meeting the market's demand. Such a limit was a very general problem, which emerged in Italy especially in times of plague, and was an endemic constraint of English manufacture. Nonetheless, it is also known that the difficulty of producing enough paper from the rags available only started to escalate in the 18th century and became utterly unsustainable in the subsequent century. Following the lead of the paper historian Dard Hunter, the problem of rags has long been mentioned as the sole motivating factor when introducing the earliest attempts in Europe to use alternative raw materials.[348] As a consequence, the literature has overlooked the emergence of such experimentation in making paper with new fibres and considered the phenomenon simply from the perspective of the emancipation of its manufacture from the consumption of linen textiles. In this chapter I will argue that such a narrative managed to capture only a limited aspect of a more complex picture. The present research suggests that the experimentation for making paper with materials other than rags, in the 17th and 18th centuries, had a different and wider scope. The first attempts actually emerged from the investigation of the natural world and were indeed pursued within the experiential ground of naturalists. Those experiments, which indicate

[348] Dard Hunter, a most influential paper historian, when discussing the compelling scarcity of rags in the Western world, came to indicate the paper made from asbestos as the first experimentation with alternative materials pursued by the Englishman Edward Lloyd in the late 17th century. Dard Hunter, *Papermaking: The History and technique of an ancient craft*. 1st ed. 1947, (New York: Dover publications, 1978), pp. 311-312. The idea has been acknowledged by the following generations of historians especially considering the British case and the proverbial need for rags in the country: Henk Voorn, "In Search of New Raw Materials", *The Paper Maker*, v.21, no.2, 1952, pp. 1-14. Richard Leslie Hills, *Papermaking in Britain: 1488 -1988, A Short History*, 1st ed. 1988 (London, Bloomsbury, 2015), p. 56. Mark Kurlansky, *Paper: Paging Through History,* (New York: W.W. Norton & Company, 2017), pp. 247-249. Bo Rudin, *Making Paper: A Look into the History of an Ancient Craft*, (Vallingby: Rudins, 1990), pp. 40-43.

a genuine and active interest of science in paper and papermaking, are revealing of a crucial moment of convergence of scientific and artisanal knowledge. When reconsidered under this different light, those early cases now suggest that the proto-scientific understanding of the nature of fibrous matter favourably pursued the cognition resulting from the artisanal practice. Eventually such integration enriched both the scientific and the manufacturing fields.

The present chapter will argue that, although the need for an alternative raw material to rags at some point became a propelling factor that embraced the experimentation toward the exploration of other sources, it is reductive to attribute the first experiences of scientists with paper to that limited aspiration. As we are going to see, in the earliest episodes that brought naturalists to approach the practice of papermaking, the technical process was primarily aimed at experiencing the ability of fibrous matter to be turned into paper. Those cases, as a matter of fact, were based on the more general interest in the philosophy of nature in fibres; as discussed in the previous chapter, such a focus has been a long-overlooked question of scientific significance. It had to be that implicit interest that persuaded naturalists to engage with the practice of papermakers. Paper artisans, as we are going to see, were indeed the indisputable holders of the most direct and enigmatic knowledge about fibres and their properties.

This chapter consists of two parts. In the first one, the case of the paper made of asbestos will introduce the circumstances that brought scientists to pursue their interest in the papermaking process for the very first time. The interest in asbestos represented indeed an occasion for experiencing paper as an actual material of fibres regardless of whether it was of vegetal or mineral origin. It will be clear that the contingency, related to the first appearance of the paper of asbestos, was not driven by the search for a new raw material or any condition of impelling necessity for paper manufacture, but intrinsically developed from the curiosity about that arcane mineral. We can relate other early cases of exchange and direct contact between scientists and papermakers to that particular interest in exploring the natural matter of fibres through its ability of being turned into paper. Indeed, we have the accounts of some naturalists who accessed paper mills to observe the processes of transformation of fibrous matter in the 17th and the early 18th centuries, sometimes even engaging first-hand with the practice of craftsmen. Some of these cases first occurred before the problem of rags started to urge a solution in the 18th century and, although the utilitarian potential of such investigations gradually emerged as the perspective of a rag-free paper started to be envisioned, we should rather define these episodes as experiences of knowledge prompted by a purely speculative objective.

The second section of this chapter will question what drove naturalists, and botanists in particular, to engage with the art of papermaking and pursue their direct observation of fibres in the process of being turned into paper. The section, therefore, will focus on the core of what we may call, rephrasing Pamela Smith's incisive expression, the papermakers' epistemology. [349] The expression denotes the specialist knowledge that distinguished the papermaker from any other worker inside the mill. Such knowledge concerned the most practical understanding of fibres, which allowed master papermakers to achieve control over the fibrous matter, along with the necessary dexterity and know-how to design specific properties of paper. The case of the blotting paper developed by English papermakers in the mid 18th century provides an exceptional instance for appreciating the fine level of knowledge that craftsmen had developed by that time and how their work in the end proved influential to science.

Part 1

1.1 Carta asbestina

Although occasionally mentioned, so far, the case of paper made from asbestos fibres has been regarded as a marginal episode in the literature of paper history.[350] The generic interest of early scientists in asbestos paper is known, but the very first appearance of such a peculiar artefact has never been investigated in detail. My research reveals that asbestos paper appeared for the first time in Genoa, approximately in 1646, and this fact is not of small significance. Paper made from asbestos indeed established the first attested experimentation in making paper using alternative raw materials to traditional vegetal fibres. Genoa was a most prolific hub for European paper at that time and it is rather significant that such an idea was realised where the know-how of papermaking was at one of the highest levels in Europe. Moreover, considering the solidity of the Italian manufacture at the time, the case confirms that such experimentation was not related to a manufacturers' search for replacing rags. For these

[349] The expression "papermakers' epistemology" comes from the core concept of artisanal epistemology expressed by Pamela H. Smith to designate the active knowledge artisans developed from their direct engagement with nature. Pamela H. Smith, *The body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004), p. 59.

[350] Research on Castagna's asbestos paper will soon be edited by Nick Wyatt in the *Science Museum Group Journal*. Although other recent authors have written on the historical use of that mineral, the Italian origins of the asbestos paper have not been considered yet. Rachel Maines, *Asbestos and Fire: Technological Trade-offs and the Body at Risk*. (New Brunswick, London: Rutgers University Press 2005), pp. 32-35. Clare Browne, "Salamander's Wool: The Historical Evidence for Textiles Woven with Asbestos Fibre", *Textile History*, vol. 34, I, 2003, pp. 64-73. Oliver Bowles, "History of Asbestos Paper", *Chemical and Metallurgical Engineering*, 22, no.5, 1920, pp. 208-9.

reasons asbestos paper should not simply be considered the first original attempt at making paper from an unconventional source, but also a revealing moment of convergence of science and artisanal technology and, consequently, part of a larger step forward in what has been indicated as an "organic process of knowledge production".[351] The idea behind the asbestos paper had to emerge from a twofold perspective embracing both the explorative understanding of asbestos and the potential utility of its fibres, all of which was pursued with the intention of expanding the knowledge of that mineral. The result was the creation of a new distinctive kind of paper never seen before which, despite its poor viability, established a literary credit and an encouraging case for the later experimentation on a wide range of fibrous vegetal matter.

1.2 Cassiano and the discovery of asbestos paper

Asbestos paper was conceived in a decisive phase of the direct observation of nature, along with the rising interest in fibres, which absorbed from a very early stage the inquisitive scrutiny of the Linceans and ultimately the person of Cassiano dal Pozzo. The discovery of asbestos paper is a fascinating episode, worthy of being traced here in detail for the first time as it emerges from the content of a series of letters sent to Cassiano and still held in the archive of the Accademia dei Lincei in Rome. In November 1646 Bartolomeo Lomellino, belonging to a noble family of merchants in Genoa, was writing in response to Cassiano dal Pozzo. The Roman scholar had apparently asked him about how he took possession of some stones of asbestos, along with various curious artefacts made from it.[352] Lomellino's reply was accurate. He mentioned having first witnessed the incombustible property of asbestos when visiting the collection of Stefano Gualdi in Rome.[353] On that occasion he was also informed about some asbestos found in Corsica. The following year, when visiting that island, Lomellino recalled of having found out that locals resourcefully applied such a material. They made enduring lamp wicks with asbestos or added its fibres to earthenware to improve their heat resistance. Being aware of collectors' interest in that peculiar mineral, he promptly sent some stones to Francesco Barberini, a cardinal in Rome,

[351] The expression "organic process of knowledge production", first formulated by Francesca Bray in her work "Science, technique, technology: Passages between Matter and Knowledge in Imperial Chinese Culture Agriculture", *British Journal for the History of Science*, 41, no. 3, 2008, pp. 1-26. The concept has been endorsed and extended in Pamela H. Smith, "The History of Science and Cultural History of the Material World", in Peter N. Miller (ed. by), *Cultural Histories of the Material World*, (Ann Arbor: University of Michigan Press, 2013), pp. 210-225, p. 215.

[352] The full transcription of the letter dated 24th November 1646 has been published in Giacomo Lumbroso, *Notizie sulla vita di Cassiano dal Pozzo*, (Torino: Stamperia Reale, 1875), pp. 166-168.

[353] As commonly happened on similar occasions, the virtuoso collector had given a demonstration to the distinguished visitor of the prodigious quality of the stone by burning its filaments, which endured intact. For similar cases see: Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy,* (Berkeley: University of California Press, 1994), pp. 224-226.

and also took some for himself.[354] In his letter he thus mentioned to Cassiano of having shown asbestos to the Carmelite friars in Genoa. They, in turn, heard from some coppersmiths that similar fibrous stones could also be found in the mountains nearby. Once he obtained some of those stones, he reported that a converso friar of the Carmelites had ingeniously wanted to try to make something out of it. Lomellino thus sent to Cassiano some artefacts made by Celso Rombo, which was the name of the friar. That letter did not specify in detail what was sent, except for a small purse, which Cassiano apparently had already seen, and a yarn that he intended to send to him soon. The letters that Lomellino sent to Cassiano, currently housed in the Lincei archive in Rome, reveal how objects were at the centre of a busy network connecting early naturalists and collectors, virtuosi and craftsmen. They also provide an extraordinary record of the circumstances from which the asbestos drawing, now in the Royal Collection of Windsor, was conceived (fig. 1). Lomellino's letters, indeed, have been appropriately indicated as being in direct connection with the drawing.[355] The literature has even better clarified the interest of Cassiano in asbestos based on the text of another missive sent by a physician in Naples to Cassiano in 1645, although the case has never been taken into account more closely.[356] From that letter it emerges that Cassiano was already looking to acquire some asbestos the year before, yet he did not require asbestos in its natural form. He apparently wanted to acquire some of it woven into a cloth. It was in textile form, indeed, that asbestos had been celebrated as a real prodigy since antiquity and in that same form it was one of the main attractions exhibited by Ferrante Imperato in his own collection.[357] The correspondent from Naples wrote that it was hard to procure the stone and even harder to find someone able to spin and weave it, suggesting who might have had some.[358]

Although we don't have the letters written by Cassiano, from Lomellino's replies we find evidence that the Lincean shared the common enthusiasm for asbestos of his peers. Nevertheless, considering the details provided in such correspondence, we must conclude that Cassiano's interest went beyond simple curiosity. He, rather, cultivated a more genuine and

[354] It might have been on that occasion that Cassiano came into contact with Lomellino, through his close relationship as a personal secretary of Cardinal Barberini.
[355] Caterina Napoleone, "cat. 134" in Mirka Beneš (ed. by), *The Paper Museum of Cassiano dal Pozzo, Quaderni Puteani 4,* (Milano: Olivetti, 1993), p. 213.
[356] Caterina Napoleone and Ian Rolfe, "cat. 255", in Henrietta McBurney, Ian Rolfe, Caterina Napoleone and Paula Findlen (eds.), *The Paper Museum of Cassiano dal Pozzo, Series B Natural History, Birds, other Animals and Natural Curiosities*, Vol. 2, (London: Royal Collection Trust, 2017), p. 622.
[357] On the legendary tradition of asbestos textiles see: Clare Browne, "Salamander's Wool: The Historical Evidence for Textiles Woven with Asbestos Fibre", *Textile History*, vol. 34, I, 2003, pp. 64-73.
[358] The indication was indeed accurate as in 1667 Della Valle described how, in 1625, he received some asbestos in Cyprus, although he could not find anybody able to weave it into the form of a cloth, similar to a prodigious one seen in Ferrante Imperato's collection. Pietro della Valle, *Viaggio di Pietro della Valle il Pellegrino*, vol. III, (Venezia, 1667), pp. 541-542.

analytical scrutiny, which was distinctive of the way the Linceans were exploring nature. Lomellino indeed answered to Cassiano reporting what he called a "secret": a description concerning the meticulous instructions of how fibres were handled. The secret revealed how fibres needed to be delicately flaked apart between the fingers to keep them as long as possible. They were also required to be sprinkled with olive oil to be gently combed and spun.[359] In such a delicate operation, Lomellino even specified how asbestos fibres, which evidently defied the spindle, required the initial lead of a linen flock in order to be spun. The technical processes involving the preparation of asbestos fibres, indeed, concerned the primary questions of the mineral's properties at its core, which distinguished asbestos from any other stone. Those traits would not have been fully discernible from a sole observation but required a practical understanding of the making process to be fully gathered. Cassiano's interest therefore was not satisfied by the sole ownership of those bizarre objects, but such artefacts captivated him for the work on the material that they entailed. Each form that asbestos was taking, whether weaved, knitted or pulped to make paper, was the expression of the material's own nature: that is how the Windsor drawing should be read.

The most recent descriptions of the Windsor drawing, mostly lured by the historical prominence of the incombustible cloth, did not pay much attention to the small fragment depicted at the bottom of the sheet, which is not "a finely woven sheet", as has been indicated, but with certainty we can say now that this is a fragment of paper.[360] Two other letters from Lomellino, dated 13 and 14 April 1646, remained neglected by the most recent literature.[361] These were respectively penned to present and accompany a parcel brought by a Carmelitan friar travelling to Rome. In slightly different words both letters contain a sort of waybill with the details of what was sent to Cassiano.[362] The contents of the parcel was thus described:

> "In the bottom there is a sheet, as large as the box, which contains the paper made from the wool and there is (also) the stone with its own wool in the way it naturally generates. Wrapped in two other large sheets, there is the same wool as it is contained within the stone. Moreover, there is another paper containing the wool

[359] Caterina Napoleone, "Appendix 16 (b)", in Henrietta McBurney, Ian Rolfe, Caterina Napoleone and Paula Findlen (eds.), *The Paper Museum, Series B Natural History, Birds, other Animals*, p. 848.
[360] Caterina Napoleone, who studied the drawing in detail, did not provide a clear definition of the fragment depicted. This has been generically defined as a "sheet" or a "finely woven sheet", possibly seen in contrast with the coarse weave in the catalogue 256, p. 624. More recently Clare Browne, writing on asbestos textiles, has indicated that the sample might represent a piece of paper, but no evidence was adduced. C. Browne, "Salamander's Wool", p.70.
[361] Accademia dei Lincei, Cassiano ms. XVII (14) fol. 234, 14 April 1646. Accademia dei Lincei, Cassiano ms. XVII (14) fol. 235, 13 April 1646.
[362] An extract of the letter was reported by the very first biographer of Cassiano, still unaware of the connection with the drawing, Jacopo Bernardi, *Vita di Cassiano dal Pozzo*, (Firenze: Tipografia Cenniniana, 1874), p. 27.

found in the rocks by the shore and another in which is a twine from the same wool. Finally, there are two small sheets: the first one wraps some thread spun from the same wool and the other contains some more wool, wider than the other one."[363]

This letter better describes the objects, later depicted in the drawing, specifying what the friar had ingeniously made from the "wool of stone" found both in the rocks from the mountains and the shore next to the convent. It also provides the evidence that the parcel not only consisted of stones and yarns, but it also included some paper of asbestos accurately wrapped, simply mentioned as the "paper made from the wool" and better described in the other letter as "paper made of the wool of stone that does not burn". That very sample of paper was the first one ever made from asbestos. Cassiano included with good reason a fragment of it in the illustration that encompassed all the forms the asbestos stone could be worked into.

The whole of Lomellino's correspondence offers so many details that makes it worth being investigated in more depth. Once contextualised, indeed, those elements reveal an exceptional combination of circumstances lying under that first idea of making paper from asbestos.[364] The entire episode can be outlined as a case of fertile convergence and the exchange of knowledge, which circulated among all the individuals involved. Lomellino had a central role in such a network, mediating between the knowledge of the learned and that of practitioners. Having acquired some cultured knowledge about asbestos himself, he was keen on reporting his personal findings to Cardinal Barberini and especially Cassiano, his personal secretary. Moreover, coming from a family of merchants who traded coral across the Mediterranean, he had the possibility to extend his knowledge when he witnessed the clever use of asbestos in Corsica for making artefacts of some interest for the learned. By sending the stones found there to Barberini, he was not just flattering a most powerful cardinal in Rome, but he was pursuing a

[363] Accademia dei Lincei, Cassiano ms. XVII (14) fol. 234, 14 April 1646: "Adamo Grapallo Carmelitano che viene costi a S. Grisogono al Capitolo presenterra' a V.S. Ill.ma in mio nome una scatola segellata e segnata col suo nome, dentro di essa vi e' nel fondo della carta fatta di quella lana di pietra che non abbruggia, poi della stessa pietra naturale come si cava dalla montagna, appresso in certe carte della lana dalla d(ett)a pietra, et di una in particolare cavata da scoglio che e' nel mare, una stringa fatta della stessa materiale, fili filati della stessa, et una carta con dentro un poco di lana piu' bella: Il N(ostro) S(ignor) Abate Borghi mi ha detto esser gusto di V.S Ill.ma haverla, havero' accio' intender che il frate l'habbi portata ben confitionata". Accademia dei Lincei, Cassiano ms. XVII (14) fol. 235, 13 April 1646 "in questa scatola sta disposto il tutto nella forma seguente; In fondo di essa in una carta che e' grande quanto il fondo di essa sta la carta fatta della stessa lana poi vi e' la stessa pietra con la lana attaccata cosi' naturalmente come nasce vi sono poi due carte grandi nelle quali e' involta della d(ett)a lana levata dalla pietra, vi e' poi un'altra carta con di quella lana che si trova negli scogli del mare, et un'altra nella quale e' una stringa fatta dalla stessa lana, per ultimo vi sono due cartuccie in una delle quali vi e' del filo filato della stessa lana, e nell'altra un poco di lana piu' longa che l'altra. Questo e' quanto vi sia in detta scatola."

[364] We can possibly consider the case as an example within the broader phenomenon of knowledge exchange indicated by Pamela Long as "trading zones". Pamela O. Long, "Trading zones in Early Modern Europe", *A Journal of the History of Science Society*, vol. 106, 4, 2015, pp. 840-847. However, the case certainly attests to the collective nature of innovation and discovery. Clifford Conner, *A People's History of Science: Miners, Midwives, and "Low Mechanicks",* (New York: Nation Books, 2007).

conversation and connecting with an erudite elite, while also aspiring at reproducing that prodigious woven artefact celebrated by all the virtuosi of his time. Lomellino possibly already had in mind who would have been able to process those fibrous stones when he contacted the Carmelites based in the hamlet of Multedo, who were especially close to his own noble family.[365] The Carmelites played a different role. Their connection with their community was deeply rooted in the social fabric of the area as the friars' activity intersected with that of the local confraternity, which had to gather the devout workers from the industrious surroundings.[366] It was thanks to such a network that the Carmelites were able to locate asbestos not far from their convent.[367] This was not easily accessible information. Lomellino shortly said that the information came from the workers of a copper foundry, but the significance of such a statement comes from the fact that only they, it being their own trade sourced from the ores traced to the nearest mountains, had the appropriate knowledge of the diverse types of rocks found there.[368]

The location, finally, is no less important than the people involved. Another key person mentioned in the account is the friar Celso Rombo. Lomellino defined him as a converso. So-called conversi, or lay-brothers, were members of holy orders not subject to ordination. These generally joined the order's life in their adulthood and, lacking a high religious education, served convents with their manual work.[369] The name of Celso, whether it was his birth name or the one he had chosen as a friar, relates him to the local confraternity, which was dedicated to the saints Nazario and Celso. This last detail, therefore, indicates that his connection with the local community was a deep one. He very possibly was a native in the area who had taken vows, maybe following a devotional path started as a member of the confraternity. Celso's likely provenance implies that he could have been familiar with the manufacture of paper, being that the industrious locality of Multedo was long concerned with that trade and manufacture. Indeed, the convent, at the centre of the local community, rose right at the lower end of the Polcevera Valley, next to Pegli, which established, along with Voltri, the notable papermaking district of Genoa and where the artisanal knowledge of paper was undoubtedly widespread and

[365] On the close relations of Bartolomeo Lomellino and his family with the Carmelites of Monte Oliveto convent see: Paolo Cevini, *Multedo: Villa Lomellini Rostan e il Monte Oliveto*, (Genova: Sagep, 1976), pp. 9-10.
[366] P. Cevini, *Multedo: Villa Lomellini*, p. 14.
[367] The information that asbestos was found next to the convent of the Carmelites in the western area of Genoa circulated among the learned and was still reported several years later. Giovanni Ciampini, *De incombustibili lino, siue lapide amianto*, (Roma, 1691), p.5.
[368] On the history of local mines of copper in Monte Ramazzo (Borzoli) see: Giuseppe Pipino, *Liguria Mineraria. Miscellanea di Giacimentologia e Storia Estrattiva*. (Ovada: Tipografia Pesce, 2005), pp. 57, 65.
[369] Stephen M.Donovan, "Conversi" in Charles Herbermann (ed. by) *The Catholic Encyclopedia*, v. 4, (New York: Appleton, 1908), p .346.

high. It was the same area in which "countless souls" made their own living from paper.[370] Considering Celso's remarkable ability in creating the objects sent to Cassiano, we can even speculate on his plausible direct involvement in the manufacture of paper.

We will possibly never know what the profession of Celso was before becoming a converso. Nonetheless, for someone coming from a community where papermaking was their bread and butter, and paper was an integral part of the everyday life, it had to be almost a matter of instinct. Being all about fibres, as we are going to see, the technique of papermaking could be purposely adapted, as papermakers had long been able to do. Foreseeing paper from a fibrous tuft, regardless and before even realising the mineral origin of those fibres, meant it had to develop as a spontaneous idea. The standpoint of a practitioner could not have been more distant from that of the learned and that is what makes this episode an intriguing case, in which the two diverging visions and different knowledge suddenly met. What appeared to a craftsperson as a natural thing to do, had to impress the naturalist, primarily involved in the taxonomical questions of the natural world. Cassiano, for his part, apparently had to be not just a passive recipient of that experience with asbestos. He certainly took part in the conversation with Lomellino and, although we don't have his letters, he conceivably was intrigued by those objects. As Lomellino's replies indicate, Cassiano had to be curious not in asbestos per se, but on how the stone was able to be worked into new forms, thanks to its fibres, responding to the manipulation of the practitioner: that very knowledge allowed the matter to be transformed and mastered. Unfortunately, we don't know with which words Cassiano greeted that first paper made of asbestos that he saw in his hands. Nevertheless, we may be sure that his analytical curiosity was not less captivated from that expressed for the asbestos cloth and especially focused on the way fibres were also treated in that other process. What we know with certainty is that the "incombustible paper", as of then, immediately became an object of interest. It fascinated an elite of cultured collectors in connection with Cassiano and, after being enlisted among the rarities of Cardinal Barberini, it partook with the same allure as the "incombustible cloth".[371] In 1655 the paper of asbestos appeared in the catalogue of the Museum Wormianum, donated to the Danish physician by a nobleman from Bologna.[372] Following the bustling network of prominent correspondents with Cassiano it is possible to trace

[370] See Chapter I, note 61.

[371] The first author to enlist asbestos paper was Panaroli, who mentioned the "carta incombustibilis ex lapide amianto" in the Barberini Museum. Domenico Panaroli, *Musæum Barberinum* (Roma, 1656), p. 6. Then Manfredo Settala, who certainly knew Cassiano and who received from him some rarities, had some. Paolo Maria Terzago, *Musæum Septalianum* (Tortona, 1664). Athanasius Kircher, *Mundus Subterraneus in XII Libros*, vol. II, (Amsterdam, 1665), p. 77.

[372] The person was named Caesar Alexander Herculanus. Olaus Wormius, *Museum Wormianum seu Historia Rerum Rariorum*, (Amsterdam, 1655), pp. 56, 351.

a selected circulation. After a few years, six sheets of asbestos were enlisted in the museum of Manfredo Settala in Milan, who was close to Cassiano and possibly received them from him, like other objects.[373] Athanasius Kircher also housed some asbestos paper in his collection in Rome, which was possibly received from Settala or even from Cassiano himself.[374] With its first appearance, the paper of asbestos thus had led the interest of naturalists from a simple curiosity for the mineral toward the more practical aspects of the transformative property of its fibres.

1.3 The asbestos paper between the scientific and the artisanal knowledge

In recent decades a new light has been shed on the way science historically developed.[375] More than just being based on an inexorable progression of theories, science history is currently contemplated with regard to its social and material contexts, which inherently resulted from human engagement with the environment.[376] From such a widened perspective, Pamela Smith's research came to highlight a new standpoint toward practice and the role of the experiential knowledge. From her studies, the manipulation of natural materials emerges as an actual process of knowledge production which, eluding textual transmission, entailed direct experience through the act of making within laboratories and workshops.[377] According to Smith, in such a gradual development, which could be traced back to antiquity, the mid 17th century finally put an end to the Aristotelian hierarchy of knowledge.[378] When that phase occurred, the artisanal techniques were acknowledged as vital standpoints to look into nature's laws. Direct experience had turned out to be crucial to the knowledge of nature and a number of institutions, such as the academies of science and societies that were established at that time, were the resulting phenomenon of that new view.[379] This background suitably contextualises the case of asbestos paper and the rising scientific interest in how paper was generated from the matter of fibres. That case, indeed, was part of a larger phenomenon in which artisanal practices were becoming ways to actively investigate nature. Papermaking made no difference. In the examples that we are going to consider, rather than being aimed at finding solutions to

[373] P. Terzago, *Musæum Septalianum* (Tortona, 1664), p.127. On the donation from Cassiano see p. 58.
[374] A. Kircher, *Mundus Subterraneus,* p. 74.
[375] The volume *The Structure of Scientific Revolutions* by Thomas Kuhn is generally considered a turning phase in such a new vision.
[376] Pamela H. Smith, "Science", in Ulinka Rublack (ed.by) *A Concise Companion to History*, (Oxford: Oxford University Press, 2011), pp. 268-297, pp. 270-272, 287.
[377] Pamela H. Smith, "The History of Science as a Cultural History of the Material World", in Peter N. Miller (ed. by) *Cultural Histories of the Material World*, (Ann Arbor: University of Michigan Press, 2013), pp. 210-225, pp. 214-215.
[378] Pamela H. Smith, "Laboratories", in Katharine Park, Lorraine Daston, Dorothy Ross (eds.) *The Cambridge History of Science, Early Modern Science*, vol. III, (Cambridge: Cambridge University Press, 2006), pp. 290-305, p. 301.
[379] Ibidem.

the problem of rags, making paper emerged as a privileged way to investigate the properties of fibrous matter.

Since antiquity, the ambiguous aspect of asbestos had brought naturalists to regard it as a noteworthy material.[380] As a stone that took the form of a woven cloth, it certainly was enigmatic. Furthermore, its incombustible property embodied a fascinating manifestation of the wondrous powers of nature.[381] Paper of asbestos had to reinforce such an obscure ambiguity and its resulting allure even further. While being manufactured from the fibres in roughly the same way as the most common sheets, asbestos paper, being invulnerable to fire, reversed the concept itself of what was ordinarily experienced with paper. It was, in some way, a contradictory kind of paper: one worth being construed through making.

It had to be that intellectual fascination that inspired the initiative of Marco Antonio Castagna, Venetian mineralogist and superintendent for the Republic's mines.[382] Having located a new quarry of asbestos, Castagna was determined to engage with that wondrous matter. In 1671 he announced of having processed the asbestos fluff, proudly proclaiming to be able to make paper out of it. The news appeared in an early scientific journal and consisted of a basic description of the process undertaken on the mineral in an attempt to make paper destined for a whole invulnerable volume. Bound in an incombustible cover and sewn with an analogous thread, "the book of eternity" would have been incorruptible and resistant to the injuries of the natural elements. [383] The actual purpose of Castagna's endeavour, however, was no less ambitious than his plan, which was defined in terms of "a way to come to cognition of the arcane secretes of minerals from the subterranean world" and aimed at "enriching the enlightenment of the Natural Philosophy".[384] The book, as far as we know, never saw the light and no mention survives of the production of asbestos paper around Venice. Nonetheless, the case achieved its crucial commitment to extending the knowledge of nature. The account, indeed, inspired other naturalists to follow. Only a few months later, the news of Castagna's book of eternity bounced

[380] It was not clear, at that time, whether asbestos' nature was vegetal, mineral or even animal. Rachel Maines, *Asbestos and Fire: Technological Trade-offs and the Body at Risk*, (New Brunswick, Rutgers University Press, 2013), p. 32.
[381] P. Findlen, *Possessing nature,* p. 202.
[382] Marco Antonio Castagna was an erudite eclectic involved in a Venetian sect committed to alchemy and esoterism. Federico Barbierato, Adelisa Malena, "Rosacroce, liberini e alchimisti nella societa' veneta del secondo Seicento: i Cavalieri dell'Aurea e Rosa Croce", in Gian Mario Cazzaniga (ed. by) *Storia d'Italia: Esoterismo*. Annali, vol. 25, (Torino: Einaudi, 2010), pp. 323- 357, pp. 335-336.
[383] "Di una materia ritrovata nelle miniere d'Italia dal sig. Marco Antonio Castagna", *Giornale Veneto de Letterati*, 15 Marzo 1671, pp. 17-18.
[384] Ibidem.

onto the pages of the Philosophical Transactions.[385] As the interest in asbestos widened, the credit of the peculiar paper made from it circulated.[386]

The experiment of the young Welsh naturalist Edward Lloyd moved in that direction. Having located a lode of asbestos in Wales in 1684, he eventually managed to make some paper from it.[387] Despite paper historians having inferred otherwise, the research for an alternative to rags was not contemplated in his account, as he never indicated in the text the use of asbestos in those terms. The naturalist, rather, introduced his report in the pages of the Philosophical Transactions, defining his primary analytical aim. He wanted to determine whether the linum fossile asbestinum from Wales was the same as that used by the ancients, of which he had heard about in his recent academic studies, and he did so through the most direct engagement with the material. The whole account reports his exploration of the properties of asbestos through altering and making. After a full examination of how the stone appeared as it was found in nature, he turned to observe how that substance responded to manipulation. When scratched across against the grain with a pin, he noticed how the compact matter easily split apart exposing the lanugo. He pounded the filaments of lint in a mortar, recording how the colour of the fibres whitened when exposed to prolonged fire, enduring intact even when turned red hot. He then twisted and oiled the fibres in the form of a wick that could burn with oil. Finally, being fresh from his "chymical" lectures at the Natural History Schoole in Oxford, Lloyd recalled that asbestos could also be turned into paper. He thus "resolv'd to try whether any (paper) could be made of this: which if not useful, might at least prove surprising to such as knew not the material of it, by its not yielding to the fire". Once the fibres were prepared, he brought them to a paper mill, asking the papermakers to process them according to their usual technique. Thanks to the craftsmen's insight, he could directly experience how the small particles of matter performed in the water, reporting that the ponderous mass of fibres sunk down quicker than the rag one, which required stirring the vat just before plunging the mould. As his statement indicated, he did not belittle the potential utility of the sheets he made and, despite the resulting paper being "very coarse and too apt to tear", he sent a sample to the Royal Society. He was confident of being able to acquire the necessary proficiency to make "good writing paper" with a bit more application and, as the papermakers estimated, by keeping the fibres under the mortars for longer. Rather than contemplating a possible employment of asbestos in paper manufacture,

[385] "A curious relation taken out of the third Venetian Journal dei Letterati", *Philosophical Transactions of the Royal Society*, vol. 6 for June 1671, pp. 2167-2169.
[386] For a full chronology of the knowledge of asbestos at these dates see: Francesco Carnevale, "L'amianto in epoca preindustriale: da meraviglia della natura ad oggetto di approfondimento scientifico", *La medicina del lavoro*, vol. 103, 1, 2012, pp. 3-16.
[387] Edward Lloyd (Lhuyd), "An account of a sort of paper made of Linum Asbestinum found in Wales", *Philosophical Transactions of the Royal Society*, Vol. 14, 1684, pp. 823-824.

Lloyd wanted to understand asbestos and pursued his intention by experiencing the process of papermaking as a way through which the fibres expressed their nature. The potential utility of his experience, foreseen in the realization of good white writing paper, was not Lloyd's primary target, but it was rather seen in the envisioned accomplishment of his own knowledge of the asbestos' fibres. This and other attempts at making paper from asbestos, rather than being propaedeutic to production, and despite the poor results they had to achieve, these experiences carried out within paper mills clearly constituted an investigative practice on the peculiar fibrous nature of the mineral.

A small treatise on asbestos confirmed the scientific relevance of such a practical exploration of its fibrous matter through the making of artefacts. "De Incombustibili Lini sive Lapide Amianto" was written in 1691 by Giovanni Ciampini, who was erudite and with eclectic interests in nature and science.[388] Along with a brief review of the literature from antiquity and the information on the different locations and the known varieties of asbestos, Ciampini provided a most detailed first-hand instruction on how the mineral could be processed according to the different qualities to spin, primarily, or to make paper. The technical details that he offered to his readers and the solutions to possible setbacks, like the advice of oiling the fingers to avoid the consequences of irritation to the skin, indicate his close involvement in the practice "learned from the experience, teacher of all things". On that very principle he established and wanted to disseminate his own experiential cognition of the mineral.[389]

The pragmatic knowledge engendered through the papermaking process was not limited to the case of asbestos, but also concerned the experimentation on a large variety of botanic fibrous materials. Such research, which engrossed some 18th century botanists, is currently considered by paper historians as the real foundation toward the emancipation of the manufacture of paper from rags. With hindsight, although such cases established a precursory step, especially after Reamur's well known first suggestion in 1719 that paper could be made from wood, just as wasps did, the actual ambition and scope of those experiments, at the time they were conceived, were doubtless wider. It is well known that the experimentation with paper made from innumerable species of plants was engaged in by the French naturalist Jean Étienne Guettard (1715-1786) and featured in the 1751 issue of the Journal Oeconomique.[390] In Guettard's account, besides his clear awareness of any possible valuable use with paper's manufacture, there was more than the simple result of a number of applications. He

[388] Giovanni Ciampini, *De Incombustibili Lini sive Lapide Amianto*, (Rome, 1691).
[389] G. Ciampini, *De Incombustibili Lini*, p. 14.
[390] Jean Étienne Guettard, "Recherches sur les matieres qui peuvent servir à faire du Papier", *Journal Oeconomique* Juillet 1751, pp. 76-126, pp. 76-103. Jean Étienne Guettard, "Suite du Memoire sur les Matieres qui peuvent servir à faire du papier", *Journal Oeconomique* August 1751, pp. 102-126.

meaningfully defined the outcome of his endeavour as a "botanical history of paper".[391] Since plants could be categorised by virtue of their suitability as a raw material for making paper, papermaking appeared as a way to explore the variety of fibrous matter pertaining to the botanical species, their anatomical parts, forms, consistencies and specific habitats.

The case of the British naturalist John Strange (1732-1799) was more explicit than Guettard's in adopting the process of papermaking as a speculative method. The circumstances obtained a remarkable international coverage after Strange was invited by the Botanical Academy of Cortona (Italy) to investigate the species responsible for the "natural paper" found on the ground after a flooding.[392] His dissertation was edited in the form of a letter in which Strange reported the results of the wide-ranging analysis he undertook.[393] After he considered the literature, which also included Guettard's direct observations, he examined the minute structure of the matter under the microscope and made some comparisons. Finally, in order to extend his understanding, he brought some samples of the conferva plinii, the plant that he assumed to be at the origin of the natural paper, to the nearest paper mills in Pistoia. The event became exemplary of the difficulties that might have easily occurred in the exchange between scientists and craftsmen, whose strained condition within the mills hindered their availability to innovation. Papermakers, likely forced to work at a hectic pace and possibly pestered by the pedantic request of the foreign scientist, omitted the preliminary maceration advocated by Strange. The result was an inevitable failure as the resulting sheets rotted soon after. Strange, however, persisted in searching for confirmation of his analysis by making paper after he found a like-minded amateur practitioner who offered to produce some samples as instructed and with appropriate means.[394]

Another well-known case worth mentioning is the experimentation of Jacob Christian Schäffer (1718-1790). The German botanist is generally considered a most influential figure for the development of alternative raw materials in papermaking, thanks to the 1767 edition of a book containing a large number of allegedly rag-free samples.[395] Despite an unstated amount of rags being actually used, as Francesco Griselini earlier ascertained and later analyses confirmed, the reception and the impact of the volume had been substantial on the later search

[391] J. Guettard, "Recherches sur les matieres", pp. 85, 101.
[392] John Strange, *Lettera sopra l'origine della carta naturale di Cortona*. (Pisa, 1764). John Strange, "An account of an essay on the origin of a natural paper, found near the city of Cortona in Tuscany", *Philosophical Transaction of the Royal Society*, January 1769, vol. 59, pp. 50-56. "Lettre de M. Strange a M. Maty, traduit de l'Anglois, sur l'origine d'un papier naturel", *Observations sur la Physique, sur l'Histoire Naturelle et sur les Arts*, Juillet 1771, pp. 43-46.
[393] J. Strange, *Lettera sopra l'origine della carta*, p. 36.
[394] J. Strange, *Lettera sopra l'origine della carta*, p. 70.
[395] Jacob Christian Schäffer, *Versuche und Muster ohne alle Lumpen oder doch mit einem geringen Zusatze derselben Papier zu machen* (Regensburg: 1765-1767).

for new materials.[396] Therefore the legacy of Schäffer's work, established around his paper samples, overlooked his underlying concern on the properties of fibres. Such interest rather emerges from the wide applications that he also wanted to experiment with. The purposed understanding of fibres in his research was not limited to paper. His extraordinary volume, therefore, along with the renowned samples of paper, also contained several swatches of fabric (fig. 4.1a), a knitted example from the black poplar cotton-like catkins (fig. 4.1b) and even a lace from the fibres of aloe leaves (fig. 4.1c).[397]

As the case of Schäffer suggests, the scientific extent of the experimentation raised around paper is what made of it a range of long-term valuable experiences. The knowledge pursued on fibres and their properties was transferable to more than the sole manufacture of paper, as there could have been more applications. In conclusion, the practical research engaged in by naturalists on papermaking should be considered as a first step towards the inception of a proper science of fibres. This fact can only be appreciated when we consider the wide-ranging reach of scientific investigation and the consequences that this specific field has on us today. In the case of asbestos fibres, although their acquaintance did not lead to any substantial advancement in paper manufacture, the wealth of knowledge gathered had been crucial to the later development of asbestos technology in the 19th and 20th centuries.[398] At that time asbestos manufacture thrived from countless applications, whose relevance in the good, but unfortunately also in the bad, cannot be assessed due to the extreme health hazard the mineral is grievously known for today.[399] More significantly, the consequences of that early scientific engagement with the fibres are an integral part of our world today, expressing in the abundance of materials, either natural or artificial, concerning every area of development, from the textile industry to construction, medicine and engineering. Should someone ever foresee a comprehensive history of fibres, they could definitely not leave paper out of their consideration. The undeniable impact that such an understated material had contributed to inspire us when designing our contemporary material landscape.

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[396] According to Griselini, who was sent a copy of the book from Schäffer, the asbestos sample was not exclusively made of the stones' fibres as the paper when placed in fire miserably turned into ashes. Francesco Griselini, *Dizionario delle arti e dei mestieri*, IV. (Venezia, 1769), pp. 223-225. Some later analysis revealed that rags were amply used along with other vegetal materials. Henk Voorn, "In search of New Raw Materials", *The Paper Maker*, v. 21, no.2, 1952, pp. 1-14.

[397] J. C. Schäffer, *Versuche und Muster*.

[398] Rachel Maines, *Asbestos & Fire. Technological Trade-Offs and the Body at Risk*, (New Brunswick: Rutgers University Press, 2005), pp. 173-179.

[399] The decrease in the statistics of fire deaths in the US after the mass introduction of asbestos as a building material, in the decade after the Second World War, is remarkable in the light of the tragic consequences well-known today. R. Maines, *Asbestos & Fire*, pp. 17-19.

1.4 Epilogue

A marginal question may appear unsolved at this point. During my research and by considering the events discussed so far, I was gradually persuaded to think that the blue sheet used for Cassiano's drawing could have been the one leaf of the asbestos paper that he had received from Genoa. With the thought of that possibility in mind, I requested the conservators of the collection at Windsor examine the material support of that drawing for me, in order to see whether some asbestos could be found. I was fortunate enough to be invited to look at that paper with their own magnifying devices, together with a conservator. What I could not expect to find is that it was not possible to interpret exactly what we were looking at. The entanglement of fibres was so impenetrable, as the figure demonstrates, (fig. 4.2) that it was hard to isolate individual filaments without physically separating some of them from the rest of the mesh: something we were clearly not allowed to do. Therefore, whereas some fibres appeared to be more visible than others, their respective nature was very difficult to identify even for an expert eye, not to mention the hurdle of recognizing any asbestos among them. The conclusion has been that the presence of asbestos could not be excluded. If there is any, it would not be easy to detect even with their best optical instruments. Identifying asbestos in that paper would ideally require extracting a small sample and burning it, in order to see whether any fibre remains intact: a pretty rough but undisputable method to my eyes, which inevitably recalled the efficacy of the spectacular experiments of the apothecary Ferrante Imperato. More than anything, however, that situation looked to me as a meaningful metaphor of how incommensurable science's sight can sometimes be in front of apparently trivial artisanal products such as a sheet of paper. The artisanal knowledge is, indeed, going to be explored in the second part of this final chapter.

Part 2

2.1 The artisanal knowledge

Since the first interest of scientists was not primarily driven by the actual production of paper, we should reasonably address what the direct engagement with the activity of papermaking had to offer to them. Scientists were apparently observing and experiencing first-hand the phenomena revealed through the making process. They were possibly questioning

them to eventually explore the ingrained laws of nature. In other words, they were approaching the secrets of papermaking and the principles on which that technique was grounded. Whilst making, they thus tried to penetrate the knowledge pertaining to master papermakers. Such a core knowledge was based on the practical understanding of the fibrous matter. That understanding encompassed how fibres performed throughout the entire manufacturing process and, as a consequence, had to be handled in order to achieve a specific outcome.

Unfortunately, tracing the historical insight into papermakers' know-how from the written sources available to us is not an easy task. In order to fathom the actual knowledge within the craft, we miss the most significant source: the artisans' own voice. Historiography has successfully gathered second-hand accounts reporting the processes performed within the European paper mills.[400] Such descriptions, gathered through time, gradually became more and more precise, also encompassing accurate pictures of tools and even representations to scale of mechanical devices, as they can be seen in the 18th century "The Art of Papermaking" by the French scientist Joseph Jérôme de Lalande (1732-1807).[401] Despite such significant literature, which at some point also started to include details of several raw materials, very little is disclosed about the artisanal knowledge of fibres and the way papermakers went on to fine-tune their techniques.

There may have been several reasons for the silence of papermakers in writing about their craft. These artisans apparently did not partake in the cultural phenomenon that brought many other practitioners to divulge their secrets, especially in the early modern period, as part of a specific literary genre.[402] When compared to the cases of extreme secrecy and isolation surrounding some of the other crafts, such as that of Venetian glassmakers, the manufacture of papermaking appears as a more ordinary trade. Since it was not ingrained in the urban social context, papermakers felt less restricted than other craftsmen: a condition that led to an early diaspora. Paper workers had thus been spreading their basic know-how throughout Europe since the Middle Ages.[403] Such a know-how, therefore, was not as uncommon as that of other arts. Another factor, related to the rank of those artisans, had to be more determinant. The papermakers' general condition of subordination to manufacturers and mill owners placed them in a most unfavourable position, as that of proletarian workers who possessed not more

[400] Dard Hunter, *The Literature of Papermaking, 1390-1800*, (New York: Burt Franklin, 1971).
[401] The Art of Papermaking by Joseph De Lalande (1761) trans. Richard Atkinson (Kilmurry. Ireland: Ashling Press, 1976).
[402] On the phenomenon of authorship see: Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge*, (Baltimore: The Johns Hopkins University Press, 2001), pp. 102-104.
[403] Giancarlo Castagnari, "La diaspora dei cartai fabrianesi. Un'indagine storica aperta" in Giancarlo Castagnari (ed. by) *L'impiego delle tecniche e dell'opera dei cartai fabrianesi in Italia e in Europa,* (Fabriano: Cartiere Miliani, 2007), pp. 13-22.

than their own proficiency. [404] The social status of papermakers, therefore, was not nearly comparable to the prestige and self-consciousness that qualified other artisans, such as painters, architects or goldsmiths. Consequently, the disclosure of their knowledge might have not been equally honorific for any author or even a potential patron.[405] Finally, the mean material of rags that they handled might have added an even sounder reason since, as we have seen, the primarily vegetal and noble nature of paper started to accrue a meaning only in the 17th century. Given all these aspects, it should not be surprising that the core know-how of papermakers did not encounter the same interest for divulgation that had been experienced by other crafts. This means that, although historians have meticulously investigated several aspects of paper history, our understanding of papermakers' distinctive competence with regard to fibres remains somewhat limited and mostly a subject of interest for conservators or forensic paper historians. The way to explore such a proficiency today better relies on the analysis of papermakers' artefacts. Paper thus often remains as the sole source to testify to the achieved knowledge of those artisans, as the case of blotting paper is going to explain.

2.2 The blotting paper case

I became especially aware of the limited appreciation of those artisans' practical proficiency when, during my research, I encountered a sample of 18th century blotting paper. Many questions emerged when I started enquiring about the properties of such a diverse quality of paper with regard to its composition, along with the necessary awareness to produce it. My findings made of it an exemplary case of the remarkable and understated ability of papermakers. The fact that the capability of those craftsmen has remained unspoken has not only precluded our full appreciation of their work but has also impeded our understanding of the impact that their knowledge may had on a more general understanding of fibres and fibrous matter.

I came across a pink sample of paper dated to the second half of the 18th century, enclosed inside a leather bound register housed in the collection of the National Archives in London (fig. 4.3a).[406] The loose paper was apparently held between the pages on purpose, as if left after use. The function of that sheet was easy to fathom. The paper comes with some black and red stains,

[404] For the proletarian conditions of papermakers see: Leonard N. Rosenband, "Hiring and Firing at the Montgolfier Paper Mill" in Thomas Max Safley, Leonard Rosenband (eds.), *The Workplace Before the Factory: Artisans and Proletarians, 1500-1800,* (Ithaca: Cornell University Press), pp. 225-240.
[405] On the artisanal self-consciousness see: Pamela H. Smith, *The body of the Artisan. Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004), pp. 31-37.
[406] The register is held along with other notebooks in the box C108/314. The National Archives, London.

leaving no doubt that it was used to absorb the excess of ink when the register was compiled. The heavier strokes of writing regularly left ink pooling on paper, which would have easily smeared or offset on the opposite side if not left to dry before turning the page. In order to speed up the compilation, therefore, fresh ink was habitually sprinkled with sand or blotted with a suitable paper aimed at absorbing any glut.[407] When blotting paper was introduced as an item of writing equipment is uncertain. Hunter indicated that the term "blotting paper" appeared in Britain as early as in 1465.[408] He did not provide a reference for that circumstance, but he ascertained that in 1519 blotting paper was used to dry wet ink, as referred to by William Horman (1440-1535).[409] In Italy the earliest mention of the use of blotting paper for absorbing ink comes around the same date in Grapaldo's volume *De Partibus Aedium*, first published in 1494, although such a use of paper, it has been noticed, possibly derived from a practice that dates back to antiquity.[410] Therefore, what it is possible to attest to from these early references in the literature, along with several other ones, is no more than the diffusion of a long lasting practice, as an alternative to that of sprinkling sand on wet writings. With specific regard to the paper used for that purpose, the information is minimal to the point of it not being possible to infer that, in the 16th and 17th centuries, blotting paper was an article deliberately made for that function. It is more likely that the term simply denoted the unsized paper or any generic paper that, deficient of a sizing agent, could be used as such. Under the term "blotting paper" both Italian and English dictionaries, still in the 18th century, indicated a defective quality: "We call blotting paper the one that, lacking the sizing, doesn't bear the ink, but it imbibes and blots so that it is placed on the freshly penned writing to avoid smears".[411]

The blotting paper found in the register at the National Archives, however, appears somehow different from a generic paper lacking the sizing agent. Its distinctive pink colour looks undoubtedly attractive and blotting paper thereafter started to be specified in English sources as being pink.[412] What firstly raised my attention was how such a colour in the sample was cleverly achieved. When looking at the surface more closely, the paper revealed that the

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[407] Joe Nickell, *Pen, Ink, & Evidence. A study of writing and writing materials*, (New Castle: Oak Knoll Press, 2000), pp. 59-63.
[408] Dard Hunter, *Papermaking. The History of an Ancient Craft*, 1943, (New York: Dover Publications, 1978), p. 476.
[409] Ibidem.
[410] Giorgio Montecchi, "La carta come fondamento dell'Humanitas", in Giorgio Montecchi (ed. by), *Il Libro nel Rinascimento*, (Milano: La Storia, 1994), pp. 111-129, pp. 112-114.
[411] "Carta sugante diciamo quella carta che, per mancanza di colla non regge, ma inzuppa e succia l'inchiostro, onde si pone sulla scrittura, fatta di fresco, allorche non si scorbi" *Vocabolario degli Accademici della Crusca compendiato secondo la quarta ed ultima impressione di Firenze corretta et accresciuta*, vol. IV, 1738, (Venezia, 1741), p. 544. For the English dictionary see: Temple Henry Croker, *The Complete Dictionary of Arts and Sciences*. Vol 2, (London: 1765), p. 95.
[412] An early pink blotting paper was mentioned in the use of a filter. James Louis Macie, "An account of some chemical experiments on tabasheer". *Philosophical Transactions of the Royal Society* 1791, v. 81, pp. 368-388, p.379.

chromatic effect was due to the combination of fibres with different shades. Even with the naked eye, indeed, it is possible to distinguish within the mesh the blending of vivid red fibres on the whitish background along with some sparse blue ones (fig. 4.3b). The combination of the white, red and blue still today results in a magenta-ish pink sheet: a surprising effect for a paper whose purpose was merely that of absorbing ink and was to be discarded after use. The recurrent adoption of such a colour suggests the intention was for a distinctive trait, aimed at being widely recognised. Pink, indeed, became more widely known as the tint of blotting papers across the 19th century and until more recent times.[413]

The interest in the blotting sample at the National Archives was initially all about those brightly coloured fibres. With the close observation of that small sample, the crisp aspect of the red and blue fibres suggested that these were fine hair of wool. Wool fibres indeed don't fibrillate, which means they don't flake into fibrils when beaten, as vegetable fibres rather do. Consequently, they don't interlock within the paper mesh and typically look as if trapped in the sheet. Such a fact raised some questions. Although the use of wool fibres might have been trivial for the purpose of a normal wrapping paper, it appeared inexplicable with the blotting function of that paper, since wool's absorbing property is insignificant compared to that of vegetal fibres. Woollen rags, which were almost impractical in papermaking, were never considered as a raw material for the manufacture of paper. Nonetheless, these were ingeniously used from time to time to bulk up the furnish of poor-quality paper, which allowed for an increased yield through the addition of a less valuable source: an important bonus considering the escalating demand for paper and the rising cost of linen rags. Coloured woollen rags would have had a twofold advantage, it was cost-effective and aesthetic, resulting in the chromatic enrichment of paper without the cost of a dye. We know that, sometimes, ordinary blue wrapping paper was profitably made in that way by using coloured rags that would have not been usable otherwise.[414] This was a widespread practice and I was able to observe a mid 18th century example of a blue paper made using those same principles in the London Metropolitan Archive: the wrapping for a paper ream destined for the English market, which, due to its pleasantness, was reused for the cover of a notebook (fig. 4.4).[415]

Besides the sensibleness of such a practice, the presence of wool in the sample of blotting paper that I was examining remained unclear. The reason why woollen rags had always been

[413] One of the most well-known pink blotting papers is the fragment Sir Joseph Paxton used for tracing his very first sketch for the Crystal Palace in 1850, now in the collection of the V&A Museum (E.575-1985). See also: Maurice Rickards, *The Encyclopedia of Ephemera* (New York: Routledge, 2000), p. 55.
[414] Irene Brückle, "The Historical Manufacture of Blue-Coloured Paper" *The Paper Conservator*, vol 17, 1993, pp. 20-31, p.23.
[415] London Metropolitan Archive. E/MW/C/177/1.

considered a very poor material for papermaking is because wool fibres are very different from the vegetal ones.[416] We know today that the chemical composition of fibres from plants is carbohydrates, while animal fibres are made of proteins, which also differ considerably in their polymeric structures.[417] In the practice of papermaking this resulted not just, as stated, in the fact that wool fibres don't fibrillate, as they rather felt, but also in the evidence that hair is not ideal to respond to liquid ink, whereas the vegetable fibres beautifully do. The presence of wool lint in a paper intended to be used as a blotting surface, therefore, baffled my most rational understanding.

2.3 Exploring the material's design

I was fortunate enough to find that the sample in the National Archives was not an isolated example. An analogous pink blotting paper, dated approximately to the same time, was mentioned in the second edition volume written by the leading paper conservator John Krill for the exhibition "English Artists' paper", held at the Victoria and Albert Museum in 1987. Inscribed with a sketchy architectural detail, the paper was part of one of Robert Adam's workbooks, now at the Sir John Soane's Museum (fig. 4.5a).[418] The paper was described by Krill as a "grey-purple blotting paper that was made of a mix of coarse white and coloured fibres". At a personal inspection, the sample appeared indeed very similar to the blotting paper from the National Archives and the dating to the second half of the 18th century also roughly converged (fig. 4.5b).[419] After an unsatisfactory search in the literature regarding details on 18th century blotting paper produced in England, I wanted to hear directly from Krill, as a recognised authority in paper conservation, resorting to his expertise on that sample and, in particular, on the use of wool lint in paper. Krill was extraordinarily generous to share his views after a microscope analysis, kindly undertaken by the conservation scientist at the National Archives, confirmed that the pigmented fibres detected within the blotting paper were undeniably hair mixed to a

[416] Irene Brückle, Theresa Smith and Manfred Mayer, "The Evidence of the Forged Paper" in Horst Bredekamp, Irene Brückle, Paul Needham (eds.) *A Galileo Forgery: Unmasking the New York Sidereus Nuncius*, (Berlin: De Gruyter, 2014) pp. 35-59, p. 38.

[417] The Knowledge of fibres' chemical structure with regard to their properties is a relatively recent achievement due to the researches developed in England since the late 1950s. John W. S. Hearle and Raymond H. Peters (eds.), "*Fibre Structure*", (Manchester and London: Butterworths, 1963).

[418] Sir John Soane Museum, reference number: SM Adam Volume 54 Series I/80. London.

[419] The sketch is pasted along with innumerable others within the volume where many other fragments of the same type of pink blotting paper could be found as follows: SM Adam Volume 54 Series I/65, 71, 73, 74, 78, 80, 88, 89, 90, 91, 92, 94 and Series VII/22, 23, 24, 27, 33, 38, 44, 47, 60, 68, 69, 81, 167, 175. The collection of sketches is undated but a few drawings present dates ranging from 1757 to 1775.

pulp mostly composed of flax (fig. 4.6a, 4.6b).[420] The blue fibres were specified as camel's hair, while the red ones were generically indicated as wool, along with other less discernible ones in the colours of light red, brown and pale yellow (fig. 4.6c, 4.6d). The presence of several types of hair fibres, therefore, reinforced my interest in the reason for such a substantial inclusion of them in a paper that was clearly made and marketed for blotting. In the absence of any clue, and the lack of any contemporary artisanal reference, Krill considered my question and directly addressed the underlying incongruity: whereas "linen holds onto water", which makes of it an ideal material for absorbing liquids, it is not possible to state the same for hair since, as he confirmed, "wool does not attract water". He thus suggested reflecting on the properties that wool fibres might have imparted when mixed with linen in order to make an excellent blotting paper. Along that reasoning, he finally speculated on how wool could have added not just bulk but might have also conferred a "wicking action", possibly superior to linen alone. The prospect of a similar property in blotting paper was extremely intriguing to my understanding as I began delineating the traits of what in today's terms is defined as "material by design", whereby functions drive the design of materials.[421] If confirmed, such an action of paper, given by the combination of the two apparently conflicting types of fibres working in synergy, would not have been rationally conceivable when considering the properties of each fibre separately. The way that blotting paper worked could have only been gathered from the direct observation of how the two different fibres interacted when meshed in the tight paper's texture, thus deliberately creating a specific paper from such an experience. In order to ascertain such a possibility, though, Krill advised me to contact a traditional papermaker and ask about the practicalities of what wool might have done in a blotting paper. He mentioned the work of the papermaker at Griffen Mill in Ballyhaunis, Ireland, a recognised expert in replicas of historical papers with a long practical experience in reproducing different qualities for restoration and conservation purposes.[422] The contact with Christine Laver-Gibbs, the founder papermaker at Griffen Mill, was essential to understand more about how the blotting paper had been made. Ms. Gibbs engaged with my questions and, after looking at the magnified pictures of the sample, was able to infer from some details what only the practitioner's eye could have noticed, putting forward some hypotheses. From the uneven distribution of the lint compared to the rest of the pulp, she could understand that the red wool was added at the end of the process. She also observed

[420] Examination and report by Dr. Elke Cwiertnia, conservation scientist from the Conservation Department of The National Archives, London.

[421] For a definition and the historical background of the concept of "material by design": Bernadette Bensaude-Vincent, "Materials as machines" in Martin Carrier and Alfred Nordmann (eds.), *Science in the context of application* (Dordrecht: Springer, 2011), pp. 101-114.

[422] On the activity of Griffen Mill: Christine Laver-Gibbs, *The early years at Griffen Mill*, (Marcham: Alembic Press, 1999).

that the red hair had left a faint halo of pigment on the flax fibres they were in contact with, which she attributed to the different water solubility of the original dye compared to the blue one. The detail of the red lint added late in the process made clear sense for the purpose of lending some of its own red to the pulp. The use of that wool was, therefore, more ingenious than I initially thought, as the final hue of the paper was not just the simple outcome of an optical effect of juxtaposition but was cleverly calculated in advance to avoid losing any discharge of pigment from the red wool. Were it added too early in the process, part of the red colour would have been inevitably lost, which explained why only the red lint was added later. The red wool, therefore, was used not just as a component but, jointly, as a dying agent on its own. The purpose of the pigmentation of paper, in conclusion, indicated an important reason for adding the stained fibres of wool to the pulp. These details not only confirmed the ability to deal with the way pigmentation could be created both from the direct discharge and the juxtaposition of minute coloured fibres, but also suggested a certain thoughtfulness for manufacturing blotting paper as a distinctive product.

Although the use of coloured fibres for the chromatic effect was more clear, the primary question remained of why wool, and no other coloured rags, was used for the blotting paper. To this specific question Gibbs replied considering the way wool fibres affect the microtexture of paper. She stated that wool would have possibly been added especially in the presence of overbeaten linen stuff, which might have resulted in a low porosity of the sheets. Overbeaten linen fibres, she explained, produce a kind of "natural sizing", since the structure of the sheet results in it being too dense and closed for the purpose of absorbing. Wool lint, in that case, might have been useful to provide a "more open structure and possibly a better pathway through the sheet for absorbency of liquids". She analysed the paper in a more technical way and, unknowingly, described something very similar to the "wicking action" assumed by Krill only as a general possibility. From the picture taken under the microscope, however, Gibbs was able to ascertain that the fibres of flax, far from being overbeaten and densely entangled, presented a very small degree of fibrillation which, she concluded, had to result in a weak bonding and might have even required the addition of some starch to hold the matter together (fig. 17).

Reasonably, although both Krill and Gibbs had persuasively speculated on the way the combination of fibres might have worked, neither of them gave the very final word that I was looking for. This in the absence of practical evidence and the possible reproduction of a sample with the same features and combination of fibres, and with the papermaker maintaining a reserve in her conclusions.

Unexpectedly, I found an endorsement of their assumptions, along with an explanation of how blotting paper technically worked, in the 20th century literature of specialist periodicals on industrial papermaking. This source suggests a continuity in the manufacture of blotting paper with the crucial addition of wool, which apparently originated from the 18th century British technique. In 1915 the British paper trade journal "The Paper-Maker" published some detailed practical hints for manufacturers to produce blotting paper.[423] The article indicated the use of a raw material consisting mainly of "soft rags" with as much as "40 per cent. of woollen fibres" and "10 to 15 per cent. of woollen dust" along with a small percentage of recycled paper. Another 1915 recipe for making extra thick blotting paper also indicated that waste rags containing about 25% of wool were considered "essential for the production of good absorptive and retentive blotting paper" as wool, it was specified, "impart to the finished product a particularly free, loose structure".[424] Another journal, dated 1921, was even more clear in explaining how the porous material of blotting paper was obtained.[425] The article expounded that, whilst writing, printing and wrapping paper required a close structure, solidity and a degree of fastness to moisture, blotting paper necessitated the opposite. Not only was sizing to be avoided but wool and cotton fibres were considered ideal in order to obtain a high-grade blotting paper from the combination of their different features. While the collapsed tubular form of cotton's fibres appeared "originally designed for the purpose of suction", the stiff wool fibres were ideal "to break up forming interstices".[426] The blotting paper thus was described as a "continuous, coherent mesh of holes and canals, which by capillary action, enable it to suck up liquids to the requisite height".[427] Although by that time cotton supplanted the use of flax, and wool became superfluous soon after, the way blotting papers were made only a hundred years ago did not differ much in their constituents and principles from the 18th century type, and consequently had to work likewise.[428]

Supported by those insights, I could reconsider the 18th century sample of blotting paper and its features with new eyes. Although not entirely perceivable to the naked eye, the structure in the sample was indeed an extremely airy arrangement of fibres, cleverly designed to perform what physics currently defines as a "capillary action". The outcome was a structure in which the effect of creating interstices produced by wool was combined with that of under-beaten flax.

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423 "Hints on Blotting Paper Manufacture", *The Paper-Maker and British Paper Trade Journal*, November 1915, p. 511.
424 "How Extra Thick Blotting Paper is Made", *Paper: Everything regarding the manufacture, sale and use of Pulp and Paper*, Vol. XVI, June 1915, p. 11-12.
425 "Blotting and Filter Papers", *The World's Paper Trade Review*, May 1921, vol. 75, no. 21, pp. 1850-1852.
426 "Blotting and Filter Papers", p. 1850.
427 "Blotting and Filter Papers", p. 1852.
428 In 1920 the technique for blotting paper in the USA indicated the use of cotton fibres and no mention of wool was made, although a little amount was recommended for the filter paper. George S. Witham, *Modern pulp and paper making: A Practical Treatise*, (New York, The Chemical Catalogue Company: 1920), pp. 50-51.

The combination of all those fibres determined an extremely porous structure full of gaps, which allowed ink to penetrate the sheet's body by easily filling the interstices left by the wool and conjointly to be absorbed by the fibres of flax, leaving no smear behind. The effect had to occur when the blotting paper was simply laid over the ink's drop that pooled on the surface of the writing paper. The simple contact had to break the tension on the convex surface of the drop and, thanks to the principle of the capillary action of liquids, the minuscule interstices of the blotting paper determined the prompt rise of the ink.[429] Considered in such a complexity of terms, the way the blotting sample worked appears far from being an accidental result, and definitely not even the choice of a defective paper over some of better quality, as the invention of the English blotting paper has been anecdotally narrated until more recent times.[430] This appeared to me a very refined and thoughtful outcome that was worthy of being scrutinised.

2.4 A model for science

We have seen that the combination of wool and flax, due to the specific properties of each fibre, might have appeared rationally counterintuitive for the absorbing purpose of paper. The way blotting paper was conceived is not comparable to the simplest model of causality, implying a consequence of cause and effect. The use of wool would have appeared a nonsense from that simplistic perspective. The way wool functioned in the economy of the blotting paper was more subtle and, in order to be envisioned and replicated, it implied a higher level of understanding at least comparable to that expressed in scientific terms. How could the formulation of paper with such a property have been conceived? At first, I was inclined to think that papermakers might have learned about capillary action from science, but rather the opposite happened. The historical chronology of the scientific comprehension of the phenomenon of capillarity rules out that contingency. Although its manifestation was apparently first observed by Leonardo da Vinci, the definition of the scientific fundamentals that explain capillarity as we know it today were still a work in progress in the 18th century. [431] At the time papermakers were producing that blotting paper, the concept of capillary action was in an observational phase, which contemplated the experiences of the ascension of liquids in narrow glass tubes. At the same time, the principle of the surface tension of liquids was also being investigated. Moreover, the crucial interaction between the two phenomena and the actual extent of the capillary model

[429] On the phenomenon of capillary action of liquids in contact with solids: James Clerk Maxwell, "Capillary Action", *Encyclopedia Britannica*, vol. V, 11th ed. (1910), p. 256-275.
[430] "The History of Blotting Paper", *The New Hazell*, 1921, p. 770.
[431] For a full chronology of the discovery and the relations between the two phenomena: J. C. Maxwell, "Capillary Action", p. 256.

started to be better comprehended and defined only from the beginning of the 19th century. The 18th century samples of blotting paper, therefore, far from being produced according to a rudimentary composition of effects, rather reflected the complex combination of two scientific fundamentals, which physics at that time had not yet entirely formulated. We have to conclude that the ingenious functioning of blotting paper might not have been reached in any other way than through a most genuine empirical process. Certainly arising from the observations accumulated through the wide experience of the way different fibres behaved in synergy and interacted with each other, the result of such knowledge was developed by British papermakers through the practical working of trial and error. Although we can't exclude a good degree of fortuity behind the very first idea of making a specific paper for blotting, any accidental result would have been void without an extremely acute observation, not inferior to a scientific one. Such observations, indeed, brought the figuration of a functional model which, in turn, led to the conception of the design of a successful new paper around a specific function.

What followed was certainly unpredictable to any papermaker. The idea behind the blotting paper did not remain confined to one of the most ephemeral artefacts of paper manufacture. Blotting paper in the 19th century started to be observed by a French physicist studying capillarity and the laws of fluid dynamics. [432] Decharme had certainly noticed that the reason on which blotting paper worked was not far from the principle scientists had long been after. The model that papermakers had expressed in the material form, as a fertile idea embodied in their artefact, had found a receptive mind. The experiments of Decharme made him change his observations of the phenomenon of capillarity within porous bodies: instead of using glass tubes as it was done previously. The model he drew from his own observations, conceived as a tight structure of superposed strips of blotting paper, turned out to be the most efficient configuration for liquids to rapidly ascend. It was on the basis of that elementary but effective prototype, made out of small strips of blotting paper, that he could contribute to determine a basic principle of botanical physiology: how the permeable tissue of vegetable fibres could actively draw water and nutrients from soil.[433]

When reconsidering the whole case of blotting paper, some important elements can be gathered. The unspoken knowledge of fibres achieved by papermakers through their practical work and observations is what made them able to design the particular type of blotting paper, expressly produced for blotting purpose. In other words, the blotting paper was a case of

[432] Constantin Decharme, "Du mouvement ascendant spontané des liquides dans des espaces très-étroits (bandelettes de papier spongieux), compare au mouvement ascendant des mêmes liquides dans les tubes capillaires". *Annales de Chimie et de Physique*, XXIX, 1873, pp. 415-425.
[433] C. Decharme, "Du mouvement ascendant spontané des liquids", p. 425.

"material by design". Nonetheless, blotting paper was more than that. It was an artefact able to convey the underlying idea of the artisanal practice it was based on, thus contributing to significantly articulate the understanding of the principle of capillarity within the scientific milieu.[434]

2.5 The knowledge of papermakers beyond the science's rationale

That papermakers were able to deliver such a complex level of discernment of fibres is not surprising. Since its very earliest appearance in Europe, papermaking has always entailed a combination of diverse fibres. Other materials, besides linen and flax, have been included since its origin, especially for the lowest qualities of paper. One of the earliest mentions of paper in Europe, dating back to the 12th century by Peter the Venerable (1092 – 1156), has long been known. The statement mentioned paper made from shavings of old cloths, or whatever other sort of humble material ("ex rasuris veterum pannorum, seu ex qualibet alia sorte viliore materia").[435] We will possibly never know the exact range of materials the abbot meant to indicate. However indefinite, his statement inferred an intrinsic degree of flexibility of papermaking to whatever sort of fibres was available when entangled with hemp or linen. That was a core principle of the art that never ceased to be pursued and consequently explored.[436] Papermaking was therefore soundly based on an empirical understanding that had long tested how paper could, or could not, be made. English papermakers had to be especially skilled in this due to the scarcity of good linen rags and their subsequent practice on "browns". They had long experienced not just how specific types of fibres behaved better than others, but also how those performed in combinations. The whole of that hands-on knowledge was hardly ever expressed in scientific terms.

When the man of science Joseph Jérôme de Lalande observed how a master papermaker ascertained the right state of broken pulp, he reported that he took a handful of beaten pulp and observed it. Once he squeezed the water out, the pulp was open in the middle. If the texture was homogeneous and the filaments appeared short, flattened, and hairy, similar to "fly's legs",

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[434] Blotting paper is currently mentioned as an exemplary case to explain how the physical principle of capillarity works. See: "Capillarity" in Peter Walker (ed. by) *Chambers Science and Technology Dictionary* (Cambridge: Chambers, 1988), p. 131.

[435] Nicolas Barker, "The Trade and Manufacture of Paper before 1800" in Simonetta Cavaciocchi (ed. by), *Produzione e commercio della carta e del libro secc. XIII-XVIII*, (Firenze: La Monnier, 1992), pp. 213-219, p. 217.

[436] For example, a formal request dated 1622 for a patent in Venice for producing paper from an alternative source than rags that was never specified. The case suggests that some trials were carried out some time before the naturalists's interests for alternative sources started. Roberto Berveglieri, *Inventori stranieri a Venezia, 1474-1788: Importazione di tecnologia e circolazione di tecnici artigiani inventori*, (Venezia: Istituto Veneto di Scienze, Lettere ed Arti, 1995), pp. 98-99.

the breaking process was considered complete.[437] This was a critical moment in the papermaking process and de Lalande did his best to communicate a core knowledge of the art, possibly reporting how it was somehow verbalised by the craftsman. However, such an account necessarily remains an equivocal description for anyone outside the art. We would legitimately wonder how exactly the short, flat and hairy fibres were assessed and what they compared with. Moreover, the status of "fly's legs" apparently indicated a visual clue of papermakers for the fibrillation state that could vary considerably. How was that quantified? When the beating process was subsequently undertaken, de Lalande reports that manufacturers sought to set its duration with a clock.[438] However, the time varied so much according to the contingencies that they had to renounce it and rely on the judgement of the master papermaker instead. The work of de Lalande was significant. His scientific determination tried for the first time to convey the tacit knowledge of craftsmen in the most accurate possible way and his descriptions give us the most valuable insight into the way papermakers worked at the time. Nevertheless, his attempt necessarily faced the inexplicable sense of what only the life-long practice of master papermakers could have known.

That incongruity between a rational vision versus a practical one is a constant element, the same one that rendered the blotting paper initially counterintuitive from a logical point of view. Such an aspect is distinctive of the way the art of papermaking was conceived and long established. An enlightening reading provides an insight of such incongruity. This is an introductory paper written by Professor Martin Hubbe for his students of chemical engineering who enrolled in a course on papermaking. In the paper, the sequence of processes that fibres undergo in order to produce paper, from their extraction to fibrillation, dispersion and bonding, is explained to students as a series of paradoxes, each of which initially appearing contradictory in its fundamentals, until scientifically explained.[439] Such a discrepancy comes from the fact that the principles of papermaking, even if today's manufacture integrates a remarkable degree of scientific knowledge, still rests on certain key empirical foundations that have been fine-tuned and passed on through generations of papermakers.[440]

That knowledge, therefore, can be explained and explored on different levels of discernment, some of which surprisingly remain still unknown to us. A technical treatise on the manufacture of paper in 1978 admitted that, besides the strong entanglement determined by

[437] Joseph de Lalande, *The Art of Papermaking*, 1761, trans. Richard Atkinson (Kilmurry: The Ashling Press, 1976), p. 26.
[438] J. de Lalande, *The Art of Papermaking*, p. 27.
[439] Martin Hubbe, Orlando Rojas, "The Paradox of Papermaking", *Chemical Engineering Education*, vol.39, no,2, 2005, pp. 146-155.
[440] M. Hubbe, O. Rojas, "The Paradox of Papermaking", p. 146.

fibrils and the formation of a hemicellulose compound that cements them, "what exactly happens to the fibres is not fully known".[441] It is breathtaking to find out that since then, in 2013, in our contemporary world pervaded by science, the same core question of what makes paper, remains an object of scientific investigation, though at an intermolecular scale.[442] This means that new evidence is currently engendered from the humblest material of paper, as we are still extrapolating scientific knowledge and learning from what generations of artisans have been making for centuries.

[441] Julius Grant and James Young, *Paper and Board Manufacture*, (London: Technical Division, 1978), p. 25.
[442] Franz Schmied, Lisbeth Kappel, Christian Teichert, Ulrich Hirn. "What holds paper together: Nanometre scale exploration of bonding between paper fibres", *Scientific Reports* 3, 2432; DOI:10.1038/srep 02432 (2013).

Conclusion

This thesis aimed to explore the role played by paper in the development of science and technology in Europe. It pursued such a target by considering how the human engagement with paper shaped both culture and mindset between the late 16th and the 18th centuries, with a particular focus on England and Italy.

As examined in Chapter I, the traditional literature on paper history constitutes the foundation for the present research. Its narrative allowed me to outline some major aspects concerning the spread of the papermaking craft and its gradual industrial manufactural development. It also valuably helped to delineate the transition of know-how by showing how international trade and exchange determined the appearance and dissemination of the technique of papermaking, along with its variations, depending on the characteristics of the local raw materials. Furthermore, a number of studies of economic history clarified the determinant factors laying underneath the rise of the paper industry, in response to a steady growth in demand and with regard to the strains in raw material supplies. All these elements are important, and they may seem to bring into accomplishment a sensible historical picture of paper within the European context. Such a type of investigation presents an essential framework that readily applies to the study of paper as a good, as well as to that of any other commodity. However, as my research wanted to highlight, paper should be considered as something more than a mere asset. Therefore, the perspective offered by the traditional literature presents only a limited viewpoint of the historical progression concerning that material.

A study of paper that only considers its object as a mere commodity can hardly address the widest aspects concerning its rising significance and the impact that such a material had on the cultural context. Nonetheless, while historians fail to acknowledge paper as a major factor in its development, some details emerging from the traditional narrative suggest that paper constituted a complex phenomenon. Cases such as that of Domenico Peri and Matthias Koops indicate incidentally that paper significantly contributed to the same development and growth of knowledge and technology, of which it gradually became the successful outcome as a mass commodity. Therefore, while the narrative offered by the traditional historiography was insufficient to address my main research questions on its own, it suggested a new direction. Hence my investigation started from that conventional literature, but soon diverged from it as

I aspired at broadening the scope of my analysis. Encouraged by a body of recent literature addressing the practices concerning paper, which is currently revealing its resourcefulness as a versatile material, I turned my reflection onto the specific engagement of scholars and artisans with the substance of paper. From there, my analysis developed significantly with the purpose of better investigating my questions, offering a different, yet complementary, progression to the conventional perspective of paper historians.

As this thesis has argued, once we move away from the traditional literature contemplating paper simply as a good and rather consider paper as an influential tool at the core of a complex phenomenon, we are able to delineate a wider narrative of its history. In particular, exploring the three instances of "using", "looking at", and "making" paper allowed me to formulate an alternative historical insight into that material, which would have hardly emerged otherwise. Indeed, as this research sustains and demonstrates, the human engagement with the material of paper turned out to be a set of miscomprehended dynamics at the core of the progression of European development. This new perspective has been obtained by integrating into our account several meanings for paper, not only as a commodity or an instrument, but also as an artefact, and even as the outcome of a manufacturing process.

In particular, Chapter II, on using paper, focused on its instrumental aspect and showed how paper's material versatility was the key that allowed scientists to wittingly embrace a pervasive tool as a proper influential technology for the elaboration of textual and visual contents. In Chapter III, on looking at paper, I explored the shifting perception of paper as an artefact between the natural and artificial spheres. The chapter thus argued that paper started to be closely observed as an enthralling product that, by combining nature and human ingenuity, was worth being questioned for its distinctive conformation and properties. Finally, in Chapter IV, on making paper, I explored paper in relation to its manufacturing process and as an outcome of it. That final chapter demonstrated how the art of papermaking represented a direct process of applied knowledge of fibrous matter, whether embraced by naturalists as an empirical method for their study, or by papermakers for the purpose of gaining the most from their craft.

Through those chapters we have seen that the analysis of each single instance of the material engagement with paper contributed to extending our perspective over the history of that material. In other words, the three types of engagement with paper discussed in each core chapter, when considered together, help to explain how that humble product from rags was able to take an active role in its own development. On the one hand, a more sensible use of paper has possibly been a major factor in the rationalisation process of its manufacture. At the

same time, the close observation of its substance has also created the possibility to redesign the material at its core. Therefore, the engagement with paper has been determinant in its own transition toward a material redesign, as attempted industrially at the end of the 18th century.

Nevertheless, whereas all these aspects give a novel perspective on the history of paper, this thesis achieves a broader target. As defined in my research questions, my objective was to identify the role that paper had in the transition toward modernity, as well as to explore how paper influenced European development, especially concerning science and technology. Therefore, the contribution of the three core chapters of this thesis goes beyond the delineation of a broader historical perspective on paper, as mentioned earlier. As we have seen in the second chapter, experiencing any potentiality of paper for the most diverse applications was a common, instinctive act, resulting from the familiarity with that widespread and versatile material. Moreover, some distinctive applications that developed from that exploration of paper's potentialities, such as herbaria and nature prints, became especially influential when they started to shift from the practice of herbalists to that of scientists. When analysing such a passage, we have been able to observe how that apparently ordinary transition unfolded and considered all the meaningful consequences that it entailed within the rise of modern science. My research, in particular, proved that the instrumental character of paper was not limited to the elaboration of textual contents, as acknowledged by some of the current literature, but should reasonably be extended to visual ones. The role of paper, therefore, emerged as a much more complex one than what has been described so far. Reducing the significance of the writing support to the mere transmission of knowledge, which has long been contemplated as its sole function, is utterly reductive compared to its meaning as an all-inclusive medium that seamlessly combined both the transmission and the processing of knowledge. Paper indeed truly encompassed representation in all its forms, allowing scientists to consciously contemplate nature at a paper scale, extracting knowledge from it easily and profitably. This means that paper, in the hands of scientists, evolved from a simple tool into an extraordinary technology for engendering knowledge, becoming accredited as the primary material interface for extending the cognition of the world. The consequences of embracing paper in those terms, although indirectly addressed in my research, have been clearly vast.

Furthermore, as we have seen in the third chapter, the scientists' engagement with paper was also significant in raising the awareness of the material of paper itself. Hence, paper began to be an object worthy of being observed, scrutinised and questioned for what it was, as well as for what it could do and why, all of which converged into the study of fibres. A further key contribution of the thesis, indeed, is the understanding that the scientists' engagement with

paper in Europe in the 17th and 18th centuries led to a deeper knowledge of organic matter. As my analysis exposed, looking at paper's substance not only encouraged them to explore the material composition of paper as a natural mesh, artificially produced from a natural source of vegetable fibres, but also contributed to the general contemplation of organic fibrous matter, along with its functions. Moreover, the most direct observation of paper's matter and its use was by no means a passive act, rather was another significant instance of the engagement of scientists with that material, which again eased and generated new knowledge in the process.

Finally, in the fourth chapter, through a novel insight into the case of Cassiano's encounter with the first asbestos paper made in Genoa, I argued that the act of making paper demonstrated its role as an empirical process of knowledge for naturalists. By deepening my research I also identified, beyond the contingency of the single case of Cassiano, how such an empirical method of exploration was later also embraced by some late 17th and early 18th century naturalists and botanists. That early experimentation with papermaking proved to have been primarily conceived as a way of extending their knowledge of nature, rather than representing simple attempts to produce paper from alternative raw materials, as it has long been suggested. Such an insight led me to consider the uncharted artisanal epistemology embedded in the process of papermaking through the case of blotting paper. From that analysis, I could observe the subtle and tacit knowledge of fibrous matter engendered by the activity of papermaking, which laid at the core of the papermakers' proficiency and was implicitly embodied in the artefacts they produced. Therefore, not only did the process of papermaking generate knowledge, but the resulting artefacts could, in turn, become active vehicles of knowledge between the artisanal and scientific spheres. In conclusion, I argue that the result from each different instance of the material engagement with paper deeply concerned knowledge in different ways and forms. For the reasons that I have delineated through my research, the engagement with paper should be acknowledged as a significant impulse for the expansion of knowledge and, with that, a material ground for the development of European science and technology in the modern age.

As a reflection of the interdisciplinary approach and the convergence of questions that characterised my research, the results of such investigations have implications that may be of some relevance for several disciplines, beyond the history of paper itself. History and philosophy of science would possibly find that my research could explain, in very practical terms, something that a philosopher such as Latour had only speculated about. This especially concerns how some advancements in knowledge not only unfolded from our material engagement with the surrounding environment, but have also been prompted by an allegedly inert, yet pervasive

medium such as paper. At the same time, the studies of material culture would find that the focus on the relevance of a material medium may constitute a major and often missing element in the study of artefacts. This especially emerges when we reflect on the commonly overlooked material aspects and properties concerning paper objects in general, such as drawings, wallpaper, books, and documents of any kind. Moreover, with regard to the studies of the history of design, my research suggests including paper itself as an object of design: one whose complex history is deeply ingrained in the development of science and technology, of which it was at the same time the outcome and, to an extent, a cause. Finally, my research demonstrates how the integration of the methodologies, viewpoints and questions of those disciplines turned out to be a valuable approach for the investigation of phenomena that present complex and diverse cultural repercussions.

Whereas all the elements presented so far may delineate some valuable insights, the overall account offered by this thesis presents some limitations. Many of those drawbacks have been determined by the "silent" character of the subject of my research, as indicated in the introduction. It may be argued that the evidence that I have gathered can appear limited, if compared against the major effects in the development of European culture that I inferred from it. The project in itself was certainly ambitious, tracing a development in which a material changed in the eyes of its users and in which I was finding it difficult to define what paper was in the first place: Was paper determined by the matter it was made out of, by its primary functions or by a shifting idea of it in the minds of contemporaries? Analysing how that evolution affected practices was not easy, since those instances primarily happened at a cognitive level. For this reason, finding evidence was a particularly challenging task and my conclusions might have been better supported by additional clues beyond botanical illustrations. Moreover, since the actual role of paper was not openly verbalised in the primary written sources, I had to deduce some evidence directly from objects, which often requires a more difficult contextualization than the one offered by texts. Another limitation derived from the geographical scope of the research. While that choice wanted to offer an insight wide enough to be generalised for the European context, this ambition clearly presented some shortcomings, since the influence of other countries has been inevitably diminished. I tried to mitigate this aspect by including facts and personalities outside the English and Italian cases, but certainly the research would have benefited from a more international viewpoint. As a related aspect, in the most practical economy of my research, and having dealt with two very diverse countries, I have often found myself in the condition of not being able to counterbalance evidence from the Italian context with the English one, due to the different nature of the sources available.

Another kind of difficulty emerged when I realised that the original direction of the project, which was established in the preliminary phase of the study, was impeding me from appreciating how the scientific and technological developments with regard to paper had actually unfolded. In particular, the initial plan, which drove me to explore paper only through its uses, although in diversely applicative domains, was preventing me from bringing to light the wealth of questions regarding the cognition of fibres that had emerged from my instinctive curiosity and research. That problem hampered my envisioning of the final structure of the arguments until late in the process and, as a result, I had not been able to explore some aspects in detail. An example of this concerns how I dealt with the practical way in which paper affected the rationalisation of preindustrial manufacturing in Italy, in particular Genoa. Although this circumstance has been inferred through the textual source by Domenico Peri and the research of Richard Goldthwaite, a more accurate study of the material development of merchants' paperwork would possibly give a new and better insight into the role that paper had in increasing the efficiency of manufacturing in the 17th century: an important aspect to consider for studying the origin of the capitalistic mindset.

In more general terms, a study on such a vast theme as that of paper can hardly be considered as concluded and the research is indeed potentially extensible on many contingent aspects, some of which I will briefly indicate here. One of them is the study of the continued exchange between science and technology, as conveyed through the ongoing material visualisation on paper reflected in the respective genres of scientific illustrations and technical drawings. As the case of the 18th century pattern book of serial pottery, discussed in the second chapter, suggests, there is still much to be considered in the way paper eased the transition of the modalities of visualisation that pertained to science within the development of technical drawings, along with what that meant for the rise of industrialisation. Another aspect that may be reasonably studied in more depth concerns the case of the early Linceans. While my analysis explored primarily the case of Cassiano, many elements suggest that among the early affiliates there was a rising new perception of paper. This may be traced back through the personal network of Francesco Stelluti, cofounder of the Accademia dei Lincei with Federico Cesi, who was born in the prominent papermaking hub of Fabriano. This case may well uncover the details of a significant transition in the perception and use of paper in the late 16th and early 17th centuries.

Finally, a different aspect worthy of being considered concerns the study of the material of paper from the perspective of the concept of "material by design", which is currently adopted to indicate the contemporary practice of engineering new materials around some desired

properties. That idea is clearly not a recent one. As my research has highlighted with the case of the blotting paper, the same approach had already been pursued with particular resolution and proficiency in that circumstance, demonstrating that such foresight had to always be at the core of papermakers' ability to control and determine the outcome of their craft. Therefore, the concept of "material by design" can possibly be extended to the study of the intriguing design of the material of paper, along with other materials, in a wider historical perspective. In other words, paper should still be contemplated as an invaluable object of research through its many aspects, especially considering that, while its major influence may have been silent and unspoken, its outcomes have certainly been loud.

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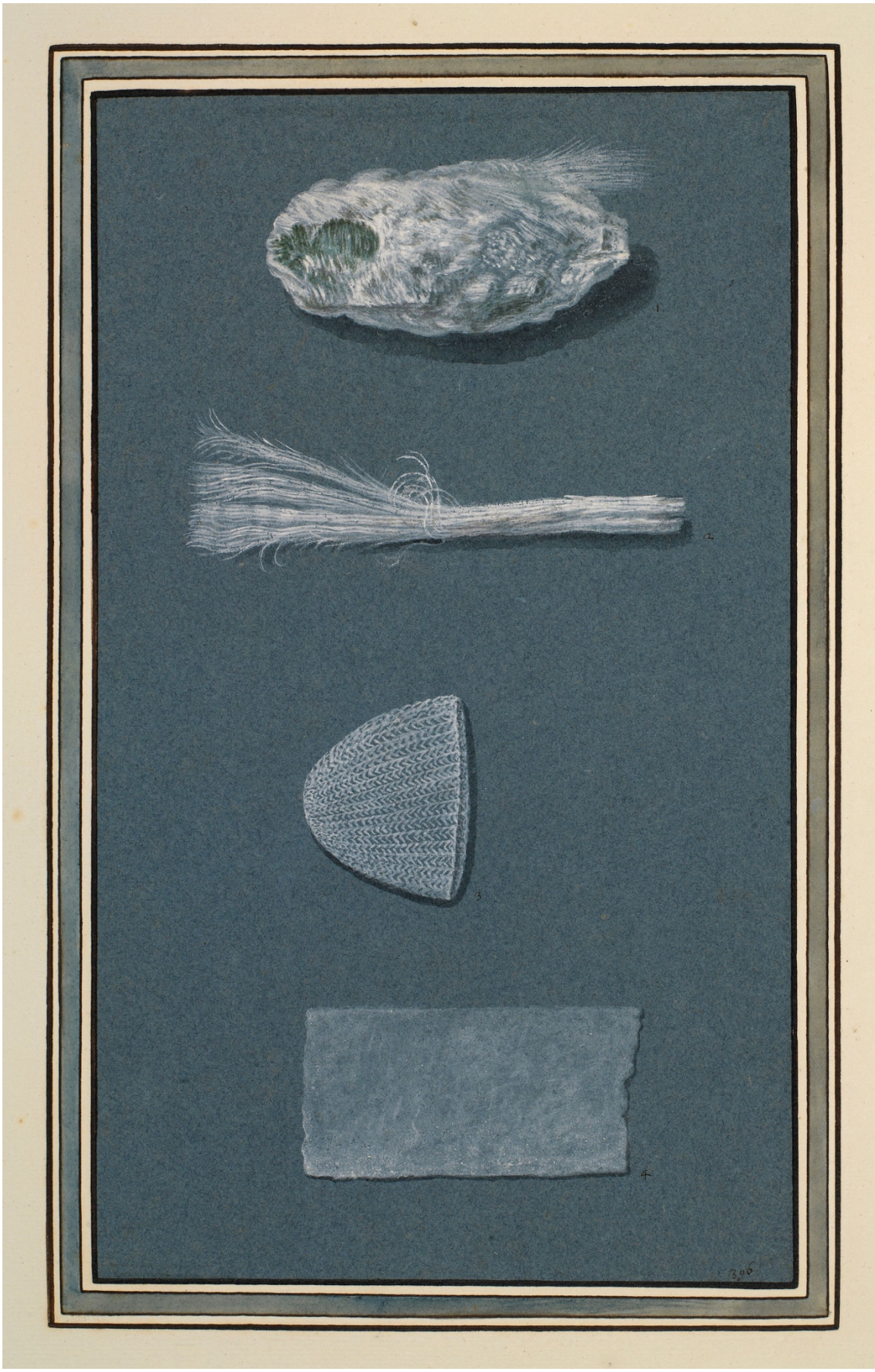
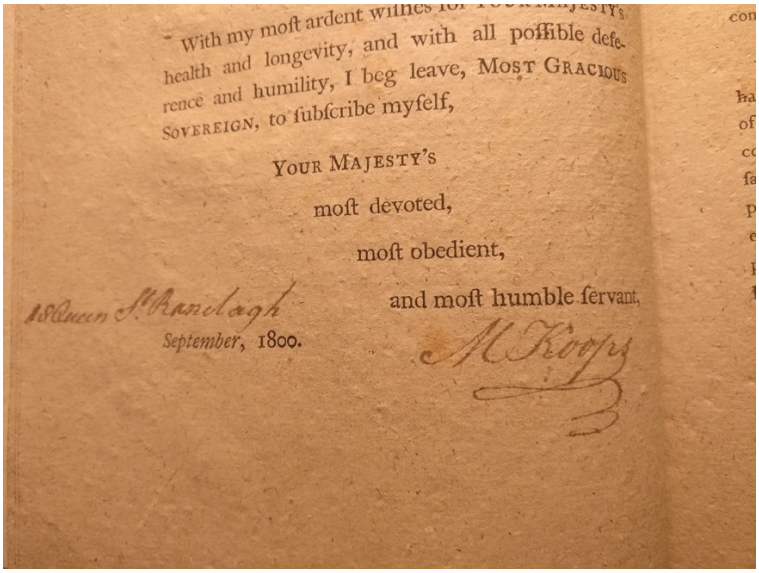
FIGURES



1. Vincenzo Leonardi (?), Study of asbestos with natural and worked samples, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018.


With my moſt ardent wiſhes for
health and longevity, and with all poſſible defe-
rence and humility, I beg leave, MOST GRACIOUS
SOVEREIGN, to ſubſcribe myſelf,

YOUR MAJESTY'S

moſt devoted,

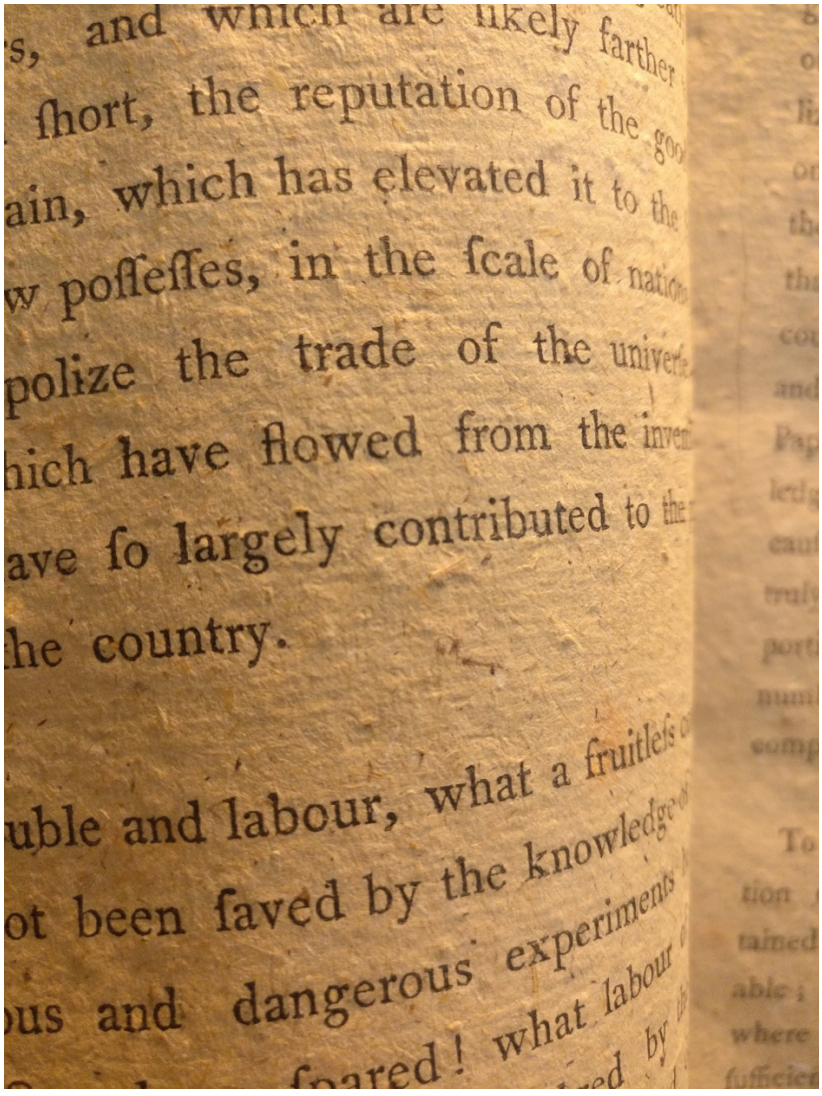
moſt obedient,

and moſt humble ſervant,

18 Queen St. Ranelagh

September, 1800.

1.1 Signature of Matthias Koops on the copy owned by Thomas Grenville. Matthias Koops, *Historical Account of the Substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper*. (London, 1800) General Reference Collection G.686. British Library, London.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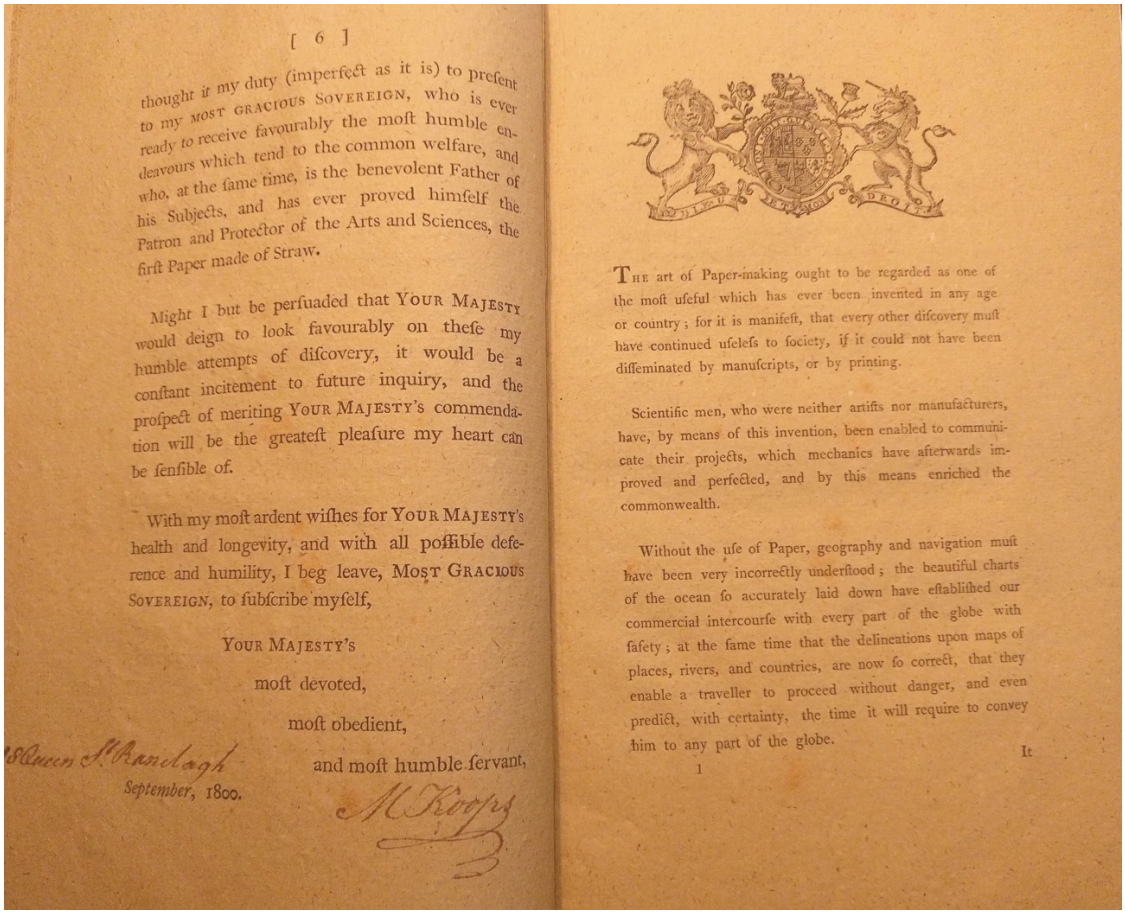
ain, which has elevated it to the
w poſſeſſes, in the ſcale of
polize the trade of the
hich have flowed from the
ave ſo largely contributed to
he country.

uble and labour, what a
ot been ſaved by the knowledge
us and dangerous experiments
ſpared! what labour

1.1b Detail of Matthias Koops' *"first useful paper manufactured soley [sic] from straw"*. Matthias Koops, *Historical Account of the Substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper*. (London, 1800) General Reference Collection G.686. British Library, London.



[6]

thought it my duty (imperfect as it is) to present to my MOST GRACIOUS SOVEREIGN, who is ever ready to receive favourably the most humble endeavours which tend to the common welfare, and who, at the same time, is the benevolent Father of his Subjects, and has ever proved himself the Patron and Protector of the Arts and Sciences, the first Paper made of Straw.

Might I but be persuaded that YOUR MAJESTY would deign to look favourably on these my humble attempts of discovery, it would be a constant incitement to future inquiry, and the prospect of meriting YOUR MAJESTY's commendation will be the greatest pleasure my heart can be sensible of.

With my most ardent wishes for YOUR MAJESTY's health and longevity, and with all possible deference and humility, I beg leave, MOST GRACIOUS SOVEREIGN, to subscribe myself,

YOUR MAJESTY'S

most devoted,

most obedient,

and most humble servant,

M Koops

Queen's Ramsleigh
September, 1800.

THE art of Paper-making ought to be regarded as one of the most useful which has ever been invented in any age or country; for it is manifest, that every other discovery must have continued useless to society, if it could not have been dissemminated by manuscripts, or by printing.

Scientific men, who were neither artists nor manufacturers, have, by means of this invention, been enabled to communicate their projects, which mechanics have afterwards improved and perfected, and by this means enriched the commonwealth.

Without the use of Paper, geography and navigation must have been very incorrectly understood; the beautiful charts of the ocean so accurately laid down have established our commercial intercourse with every part of the globe with safety; at the same time that the delineations upon maps of places, rivers, and countries, are now so correct, that they enable a traveller to proceed without danger, and even predict, with certainty, the time it will require to convey him to any part of the globe.

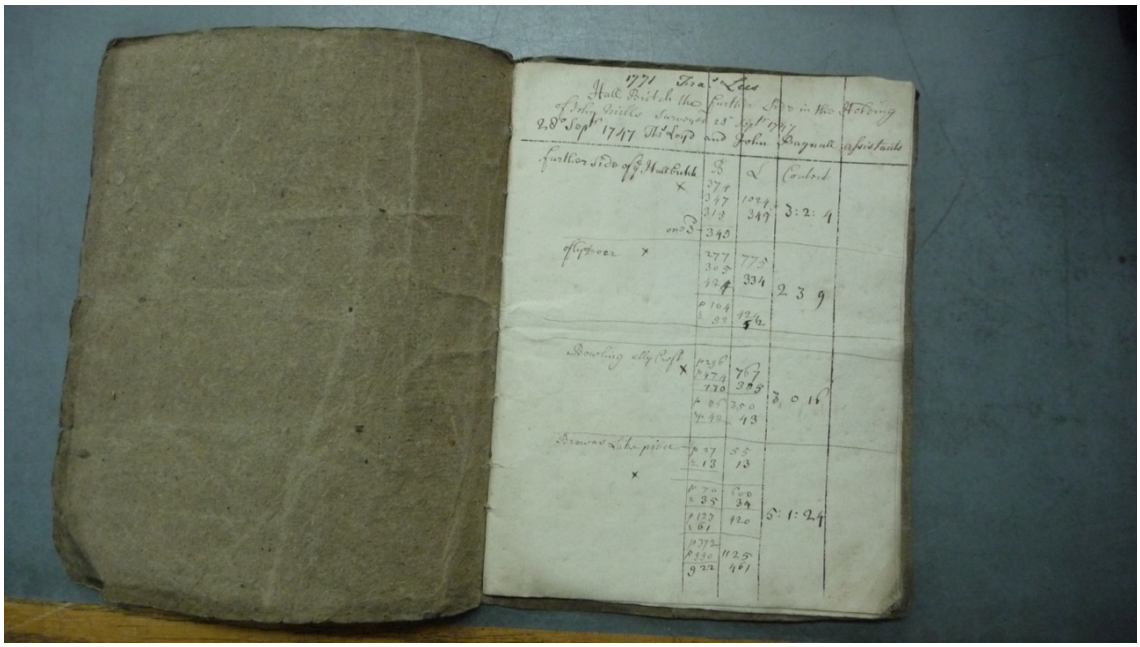
It

1

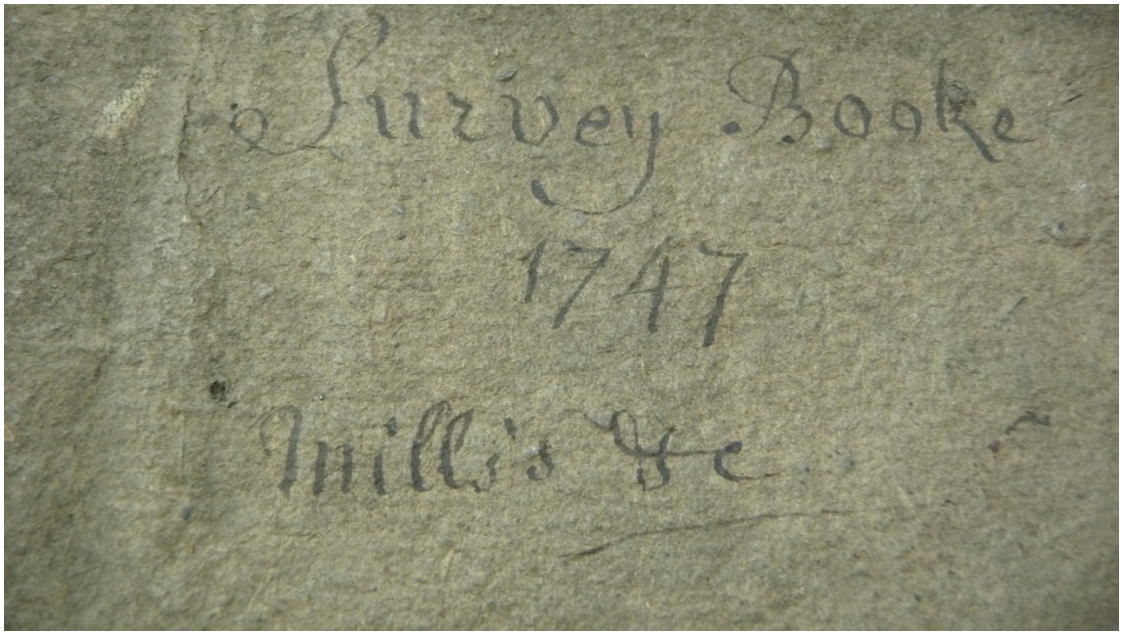
1.1c Layout of Matthias Koops' book. Matthias Koops, *Historical Account of the Substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper*. (London, 1800) General Reference Collection G.686. British Library, London.

1.2a. Sample of coarse brown (laid) paper used as a wrapper of a 1679 deed's wax seal. Late 17th/18th century ca., E/MW/C/169/2, London Metropolitan Archive.

1.2b. Detail of lump of tar entrapped within the hemp fibres mesh. Late 17th century ca.. E/MW/C/169/2, London Metropolitan Archive.



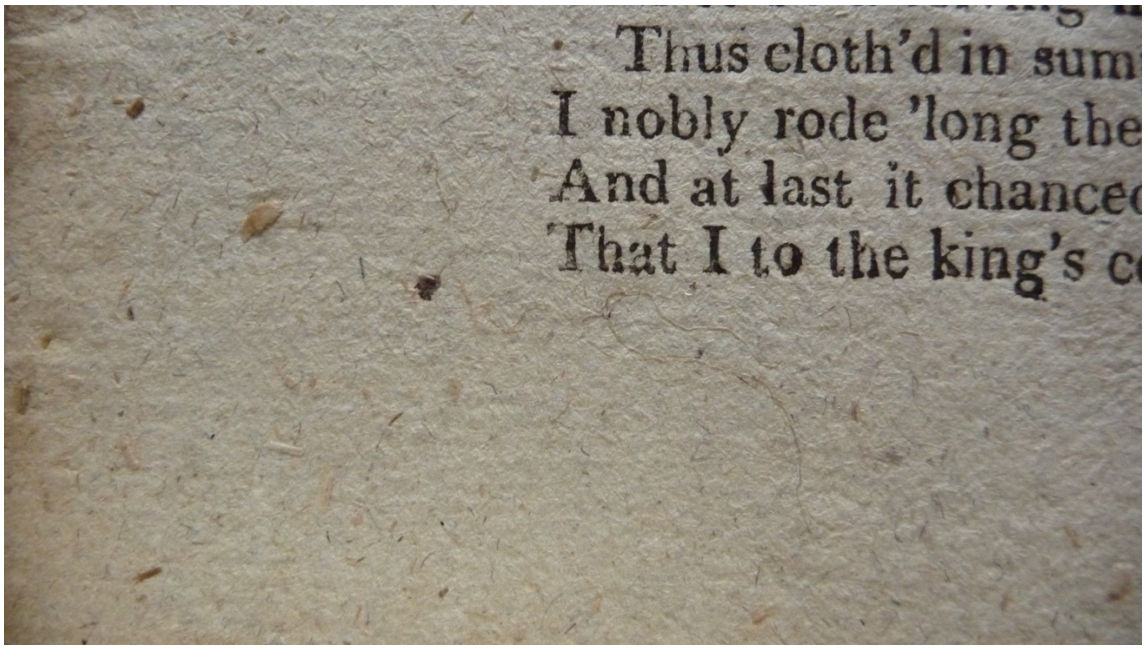
1.3a. Brown paper notebook cover, 1747 ca. C/108/314, The National Archives, London.



1.3b. Detail of brown paper notebook cover, 1747 ca. C/108/314, The National Archives, London.

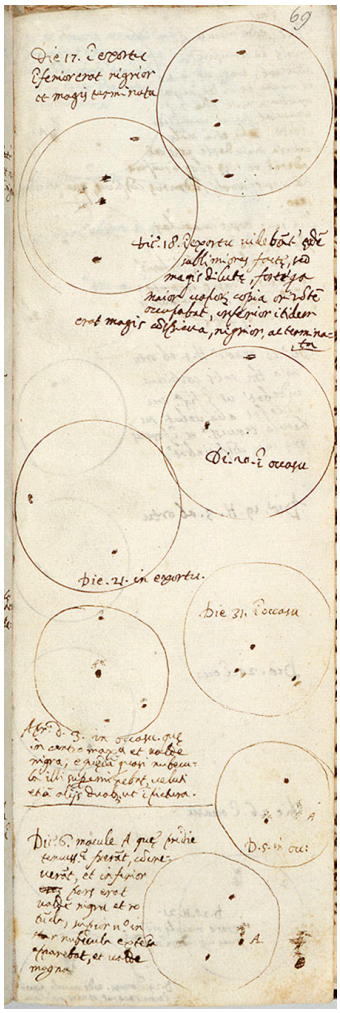
1.4a. Possible example of whited brown paper used as deeds wrapper, 18th century, E/MW/C/169/1, London Metropolitan Archives.

1.4b. Detail of a possible example of whited brown paper used as deeds wrapper, 18th century, E/MW/C/169/1, London Metropolitan Archives.



1.5a. Paper's detail of the ballad "The Famous Flower of Serving Men". Early 19th century copy. Collection of the Society of Antiquaries of London.

1.5b. Backlight detail of the paper of a copy of the ballad “The Famous Flower of Serving Men”. Early 19th century. Collection of the Society of Antiquaries of London.



2.1. Galileo Galilei, Drawings of the Sun’s spots from the telescope’ s projections on paper. Ms. Gal. 57, 69r., 1612, Biblioteca Nazionale Centrale, Florence.

2.2. Anatomical map of muscles. Andreas Vesalius, "Nona Musculorum tabula" *De humani corporis fabrica libri septem*, (Basileae: 1543) p. 194. General Reference Collection C.54.k.12, British Library, London.

2.3. Explorable representation of female anatomy. Thomas Geminus, "The anatomie of the inward partes of woman", *Compendiosa totius anatomie delineatio aere exarata*, (London: 1559), EPB 2731/D/2, Wellcome Library, London.

2.4. Ulisse Aldrovandi, cut-outs practice on the *Ranuncolaceae Consolida* page, Erbario Aldrovandi n. 14, folio 205, late 16th century ca. With the kind concession of Alma Mather Studiorum – University of Bologna, Sistema Museale di Ateneo, Erbario e Orto Botanico. Bologna.

2.5. Example of nature printing on the verso of a copy of Dürer's broadside of a rhinoceros, 1550 ca. Museum n. 1928,0310.98 ©Trustees of the British Museum. London.

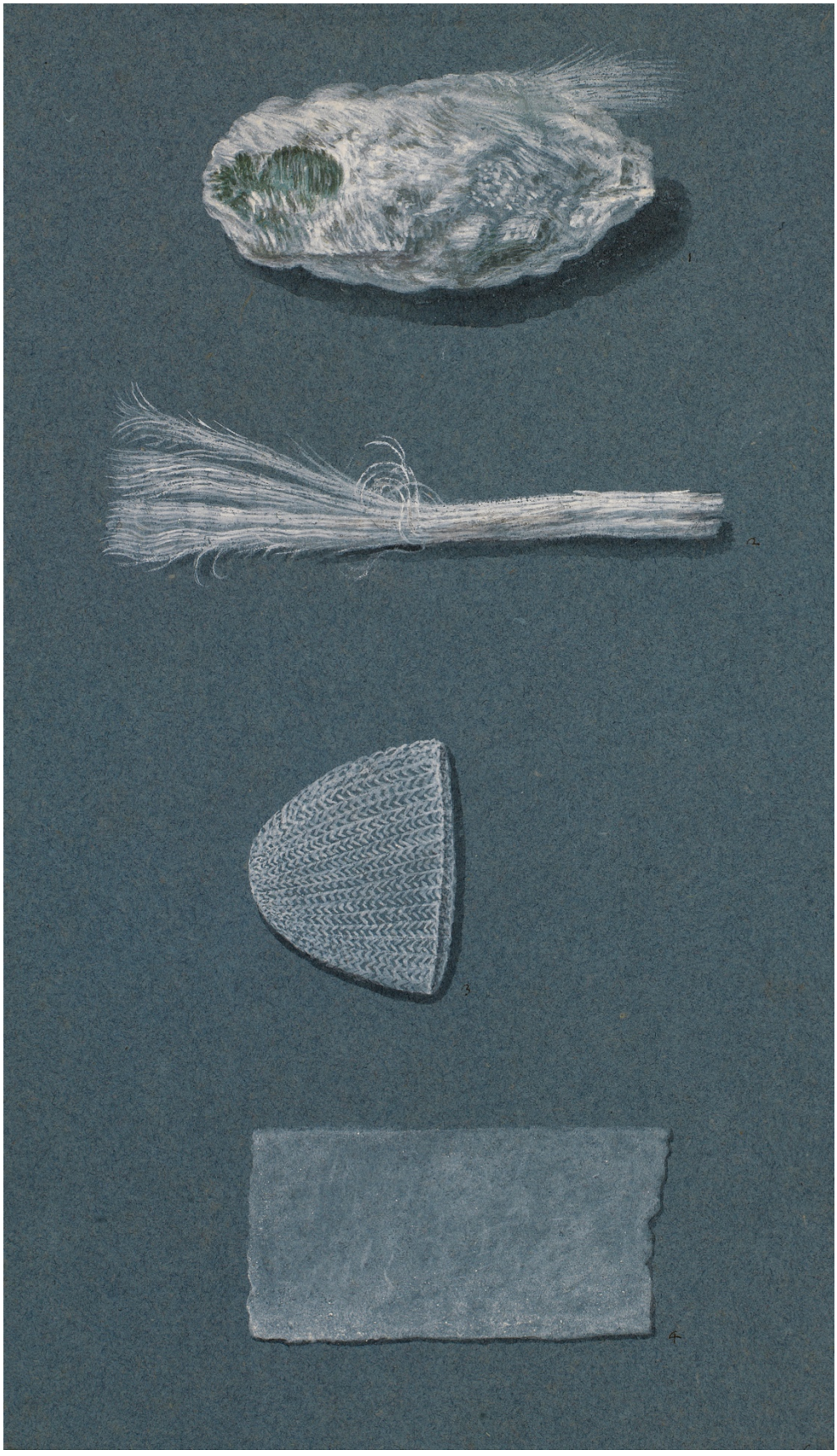
2.6. Zenobio Pacini, Illustration of bistorta officinalis, hybrid technique integrating hand coloured nature printing and painting, folio 14r. 1520 ca. ms. ISNI 4 59848 103X, Biblitheque Nationale de France, Paris.

2.7. Fabio Colonna, Illustration of a poppy from: *Iconae ipsis plantis ad vivum expressae*, folio 223r., hybrid technique of nature printing integrated with hand drawing and painting, first decades of the 17th century. Blickling Hall Library, Norfolk.

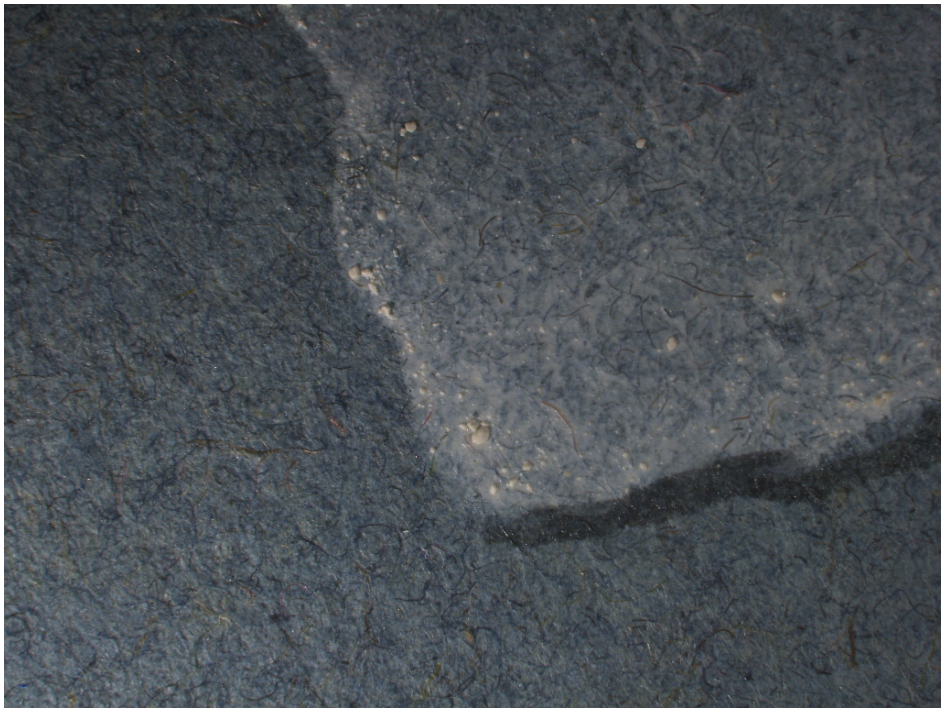
2.8. Author unknown, holly fern “seeds from microscope” from the collection of Federico Cesi, ms. 976, fol.65r. Institut de France, Paris. Brent Elliott (ed. by) Flora. Federico Cesi’s botanical manuscripts, The Paper Museum of Cassiano dal Pozzo, series B, Natural history, vol. 2 (London: Harvey Miller Publishers, 2015) p. 567. General Reference Collection: YC.2015.b.1069, British Library, London.

2.9. Author unknown, Levant cotton capsule with seeds and surrounding fibres from the collection of Federico Cesi, ms. 974, fol.17r. Institut de France, Paris. Brent Elliott (ed. by) Flora. Federico Cesi's botanical manuscripts, The Paper Museum of Cassiano dal Pozzo, series B, Natural history, vol. 1 (London: Harvey Miller Publishers, 2015) p. 111. General Reference Collection: YC.2015.b.1068, British Library, London.

2.10. Vincenzo Leonardi (?), Illustration of fungus *Hericium sp.* on a brown paper from the Paper Museum collection of drawings of Cassiano dal Pozzo, RL 19378, Windsor, Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018.

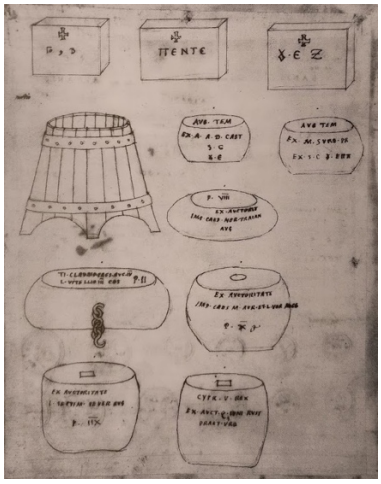


2.11a. Vincenzo Leonardi (?), Detail of the study of asbestos from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



2.11b. Magnification of the fuzzy paper of the study of asbestos from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018

2.12. Vincenzo Leonardi, detail of the drawing illustrating the anatomical parts of a crested porcupine from the Paper Museum of Cassiano dal Pozzo, RL19438, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



2.13 Left: Illustration of roman measurement units, copy from the 16th century *Codex Ursinianus* (on top) Paper Museum of Cassiano dal Pozzo, RL 10241v, Windsor, Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018

2.14. Vincenzo Leonardi, Exotic fruits and seeds from the Paper Museum of Cassiano dal Pozzo, RL25530, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018

2.15a. Illustrations from the workshop pattern book, Hartley, Greens & Co. (1778-1792), museum n. E.576-1941, Victoria and Albert Museum, London.

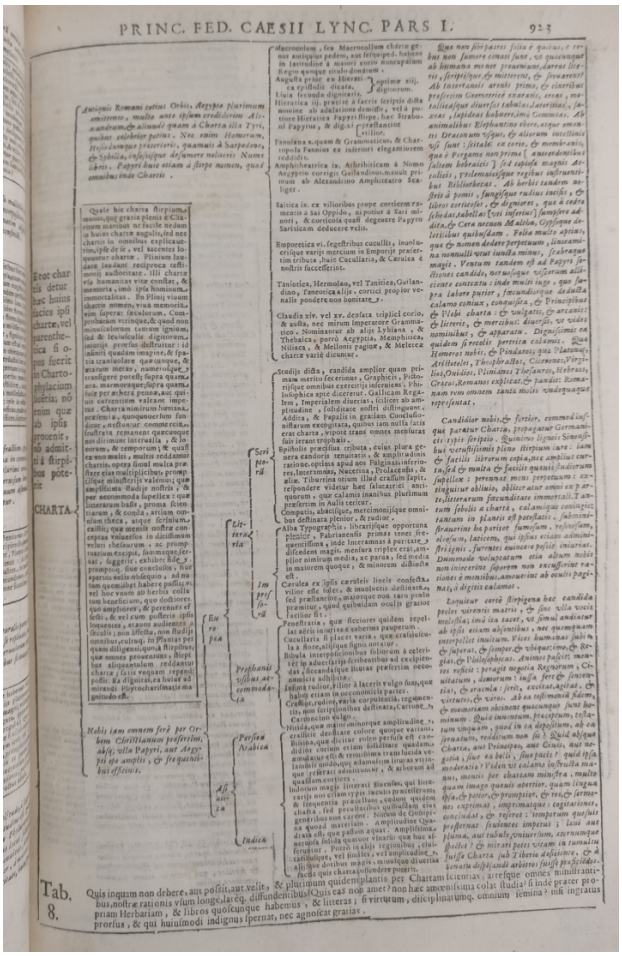
2.15b. Technical drawings from the Hartley, Greens & Co. workshop pattern book, (1778-1792), museum n. E.576-1941, Victoria and Albert Museum, London.

2.15c. Illustrations from the workshop pattern book of Hartley, Greens & Co. (1778-1792), museum n. E.576-1941, Victoria and Albert Museum, London.

2.15d. Study of the handles' position for a tureen from the Hartley, Greens & Co. workshop pattern book, (1778-1792), museum n. E.576-1941, Victoria and Albert Museum, London.

3.1. Etching illustrating Cospi in the act of presenting his collection of rarities from: Lorenzo Legati, *Museo Cospiano annesso a quello del famoso Ulisse Aldrovandi*, (Bologna, 1677). General Reference Collection 985.h.10. British Library, London.

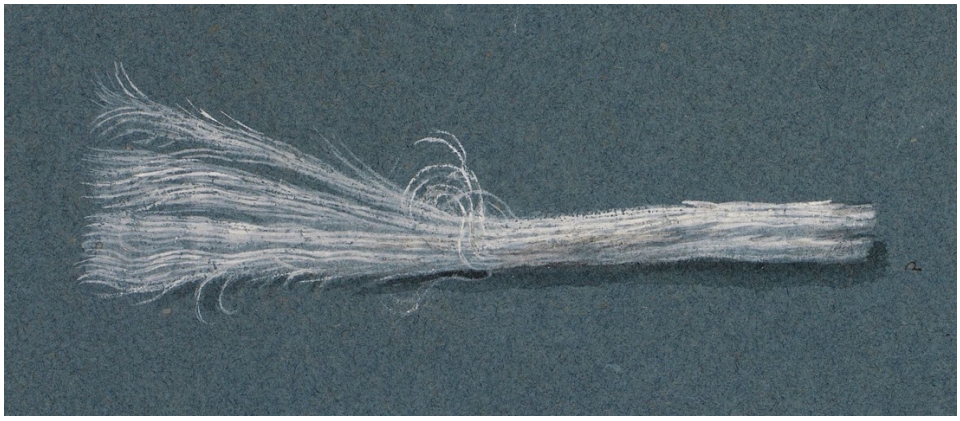
3.2. Illustration of the ship sailing beyond the pillars of Hercules from the frontispiece of Francis Bacon's first edition of the Novum Organon as contained in: Francisci de Verulamio, *Summi Angliae Cancellarii, Instauratio magna* (London: 1620). General Reference Collection C.54.f.16. British Library, London.



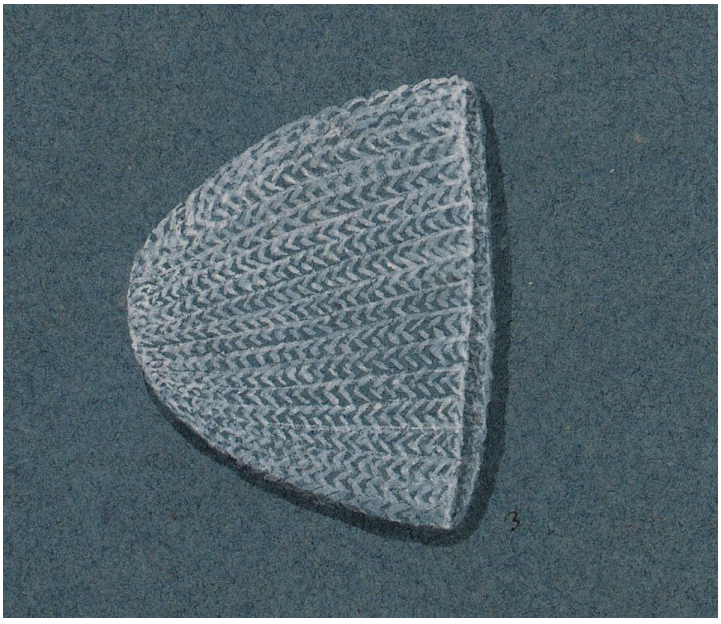
3.3. Federico Cesi, Diagram of contents from the "Phytosophicarum tabularum" in Federico Cesi et al. (ed. by) *Rerum Medicarum Novae Hispaniae Thesaurus* (Roma: 1649) p. 923. General Reference Collection 443.k.9. British Library, London.

3.4. Illustration of asbestos experiment with fire from: Ferrante Imperato, *Dell'Historia Naturale* (Napoli, 1599) p. 679. General Reference Collection 456.b.9. British Library, London.

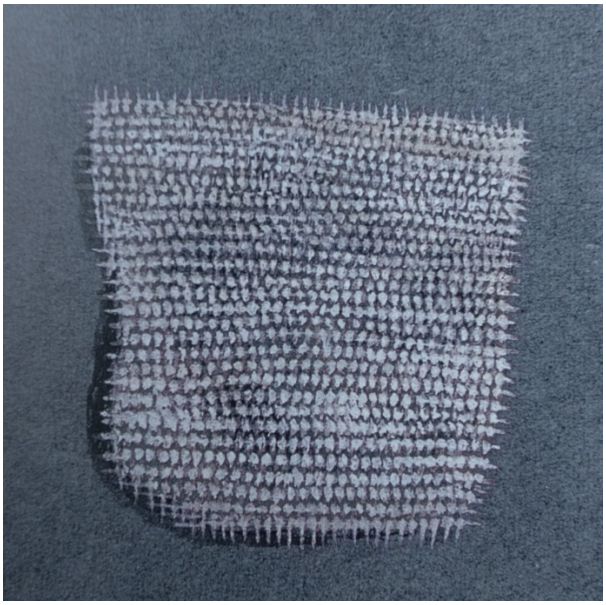
3.5a. Detail representing a stone of asbestos in its natural state. Study of asbestos, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



3.5b. Detail representing the partially unwound rope of asbestos. Study of asbestos, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



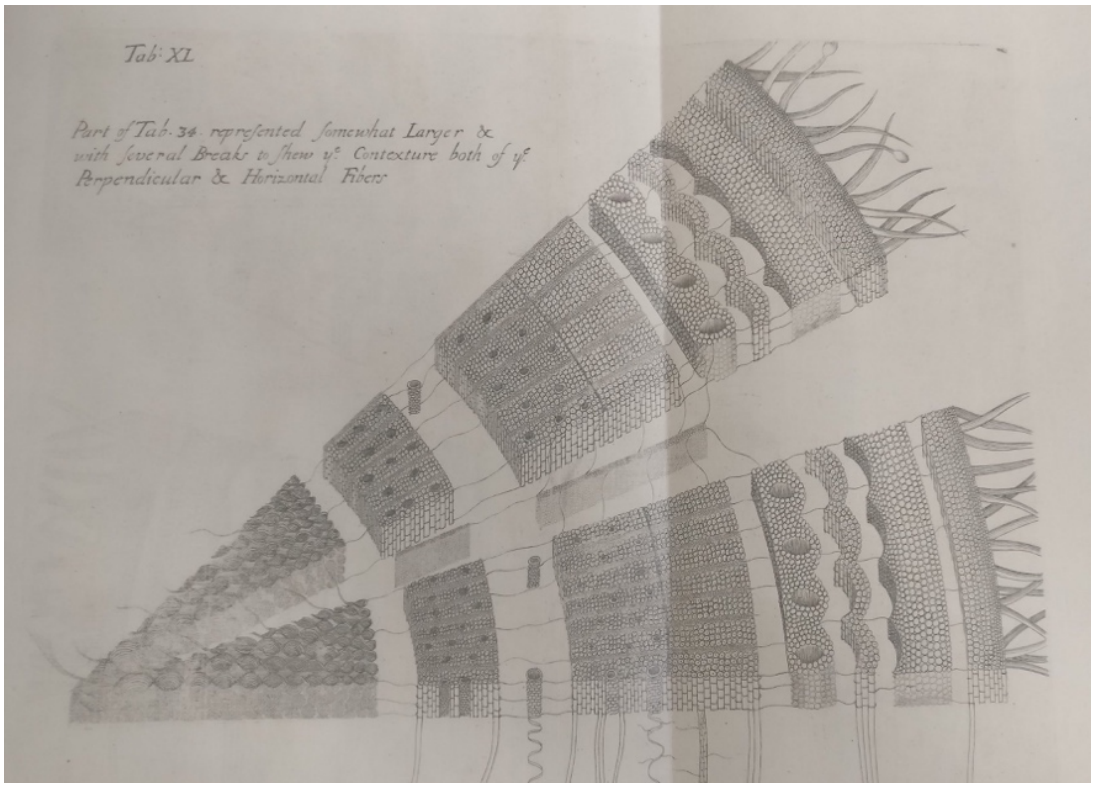
3.5c. Detail representing a knitted cap of asbestos. Study of asbestos, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



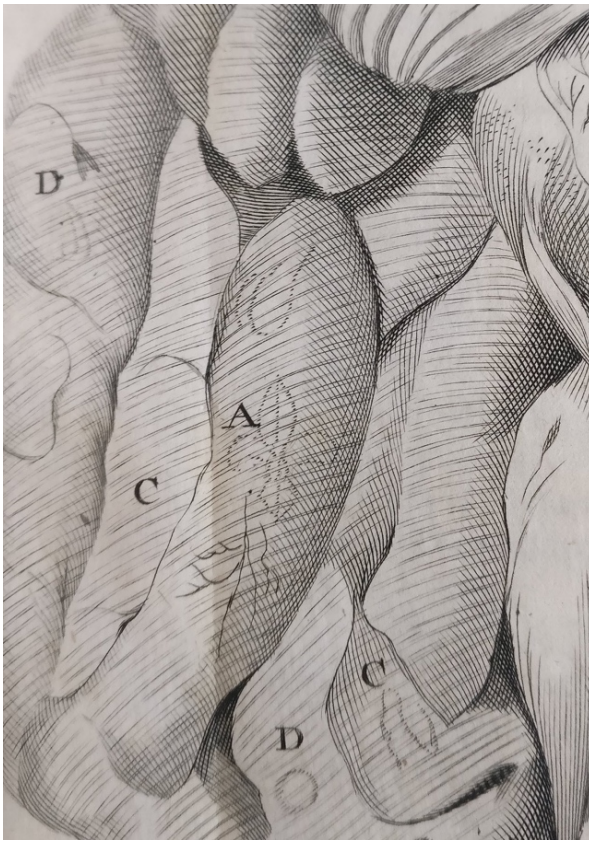
3.5d. Figure representing a fragment of rough woven cloth of asbestos. Private collection, Image from: Francesco Solinas, *I segreti di un collezionista: Le straordinarie collezioni di Cassiano dal Pozzo* (Roma: Edizioni De Luca, 2000) p. 164. General Reference Collection LB.31 b.23016, British Library, London.

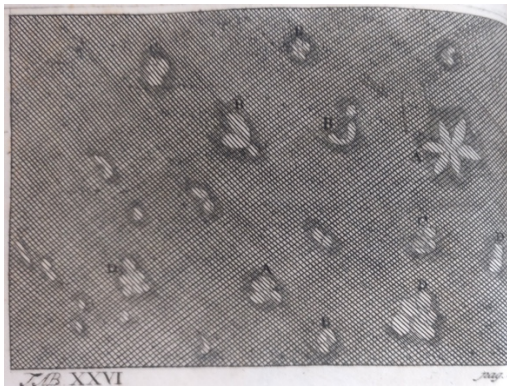
3.5e. Detail representing a fragment of asbestos paper. Study of asbestos, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018

3.6. Representations of how different directions of fibres interweave within the organic matter from Andreas Vesalius, *De humani corporis fabrica libri septem*, (Basileae: 1543). p. 258. General Reference Collection C.54.k.12, British Library, London.



3.7. Illustration of the contexture of organic fibres of a sumac tree branch under the microscope from: Nehemiah Grew, *The anatomy of plants with an idea of a philosophical history of plants*, (London: 1682) tab. XL. General Reference Collection 449.k.10. British Library, London.

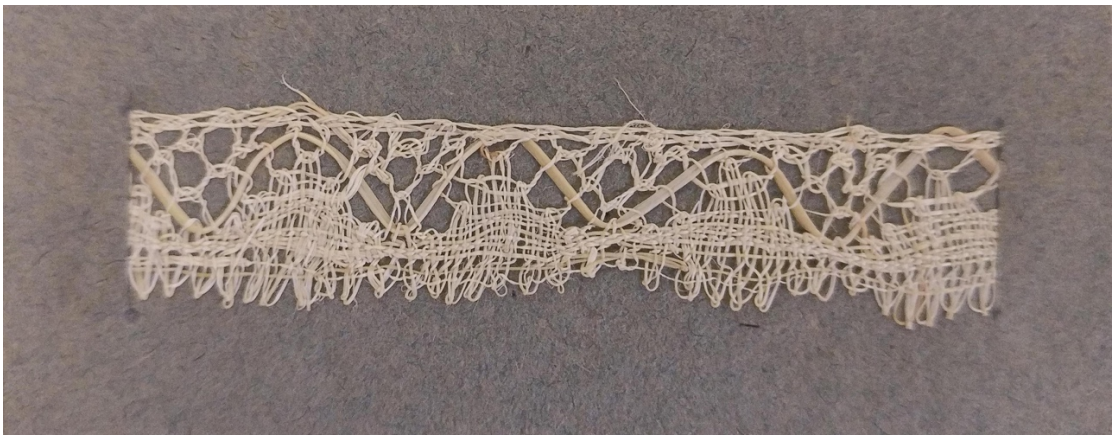




3.8a, 3.8b. Representation of how ideas take form within the fibrous matter of brain, tab. XXV and XXVI from: Theodor Craanen, *Tractatus physico-medicus de homine* (Leiden: 1689). General Reference Collection 549.d.28. British Library, London.

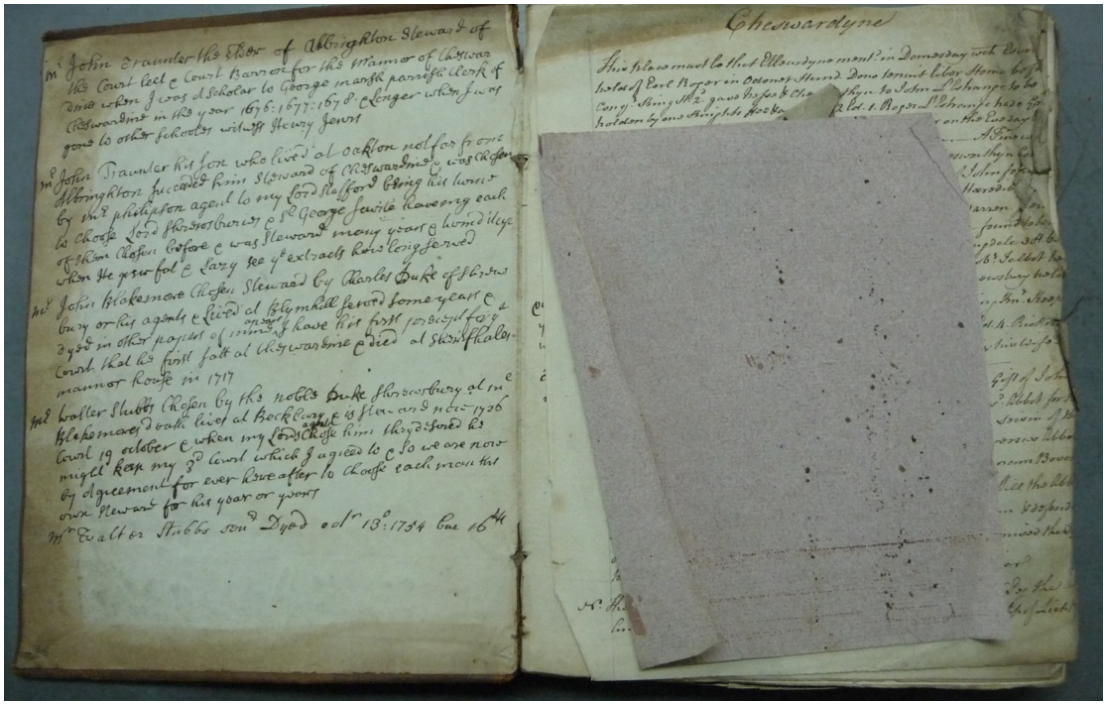
4.1a. Samples of woven fibres of Black poplar catkins from: Jacob Christian Schäffer, *Versuche und Muster ohne alle Lumpen oder doch mit einem geringen Zusatze derselben Papier zu machen* (Regensburg: 1765-1767). General Reference Collection C.112.c.2. British Library, London.

4.1b. Samples of knitted fibres of Black poplar catkins from: Jacob Christian Schäffer, *Versuche und Muster ohne alle Lumpen oder doch mit einem geringen Zusatze derselben Papier zu machen* (Regensburg: 1765-1767). General Reference Collection C.112.c.2. British Library, London.



4.1b. Samples of lace ribbons from the fibrous strings of aloe leaves from: Jacob Christian Schäffer, *Versuche und Muster ohne alle Lumpen oder doch mit einem geringen Zusatze derselben Papier zu machen* (Regensburg: 1765-1767). General Reference Collection C.112.c.2. British Library, London.

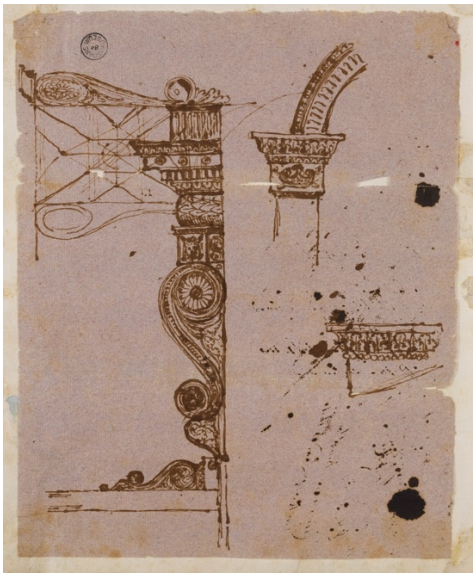
4.2. Detail of the intricate mesh of different fibres within the blue paper under the microscope. Study of asbestos, from the Paper Museum of Cassiano dal Pozzo, 1646 ca., RCIN 925522, Windsor. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2018



4.3a. Pink blotting paper as found within a record book dated to the second half of the 18th century. C108/314. London, National Archives.

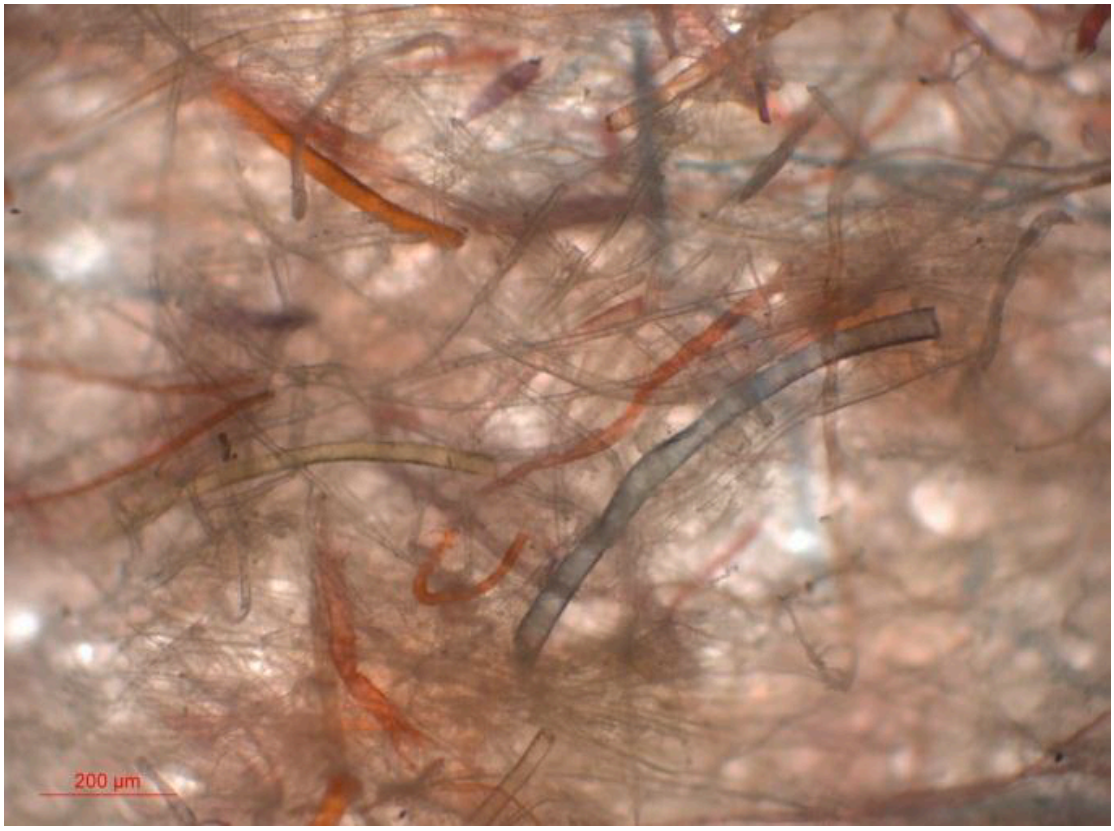
4.3b. Magnified detail of the blotting paper from the record book C108/314. London, National Archives.

4.4. Blue paper ream wrapper reused as a notebook cover 1750 ca. E/MW/C/177/1, London Metropolitan Archive.



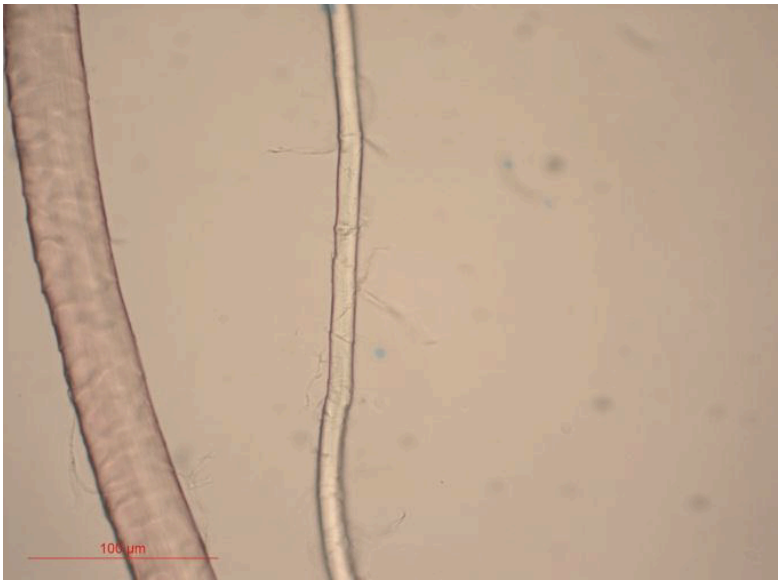
4.5a Robert Adam, sketch of architectural elements on a pink blotting paper, second half of the 18th century, reference number: SM Adam Volume 54 Series I/80, Sir John Soane Museum, London.

4.5b Detail of the red and blue fibres within the blotting paper of Robert Adam's architectural sketch, Reference number: SM Adam Volume 54 Series I/80, Sir John Soane Museum, London.



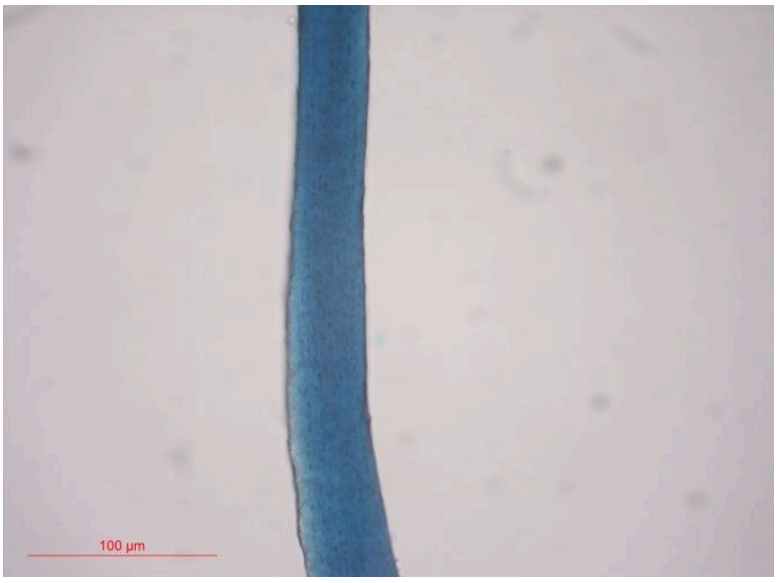
4.6a Picture of the mesh of fibres of the pink blotting paper from the National Archives under the microscope. The thin transparent fibres have been identified as vegetal fibres (flax) while the thick pigmented ones (primarily red, blue and yellow) have been indicated as hair of different type. C108/314 National Archives, London.

4.6b. Transparent thin vegetal fibre of flax with visible signs of a minor fibrillation from the blotting paper sample C108/314, National Archives, London.



4.5c Fibres of hair (left) and flax (right) from the blotting paper sample, C108/314, National Archives, London.

4.6d. Thick red hair fibre showing the typical structure of scales from the blotting paper sample C108/314, National Archives, London.



4.6e. Blue camel hair fibre from the Blotting paper sample C108/314, National Archives, London.