

Experimenting with Living Nature: Documented Practices of Sixteenth-Century Naturalists and Naturalia Collectors¹

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Abstract: This article discusses experimentation in the context of sixteenth-century natural history, or *natural science* as I prefer to call it here. It uses predominantly textual sources, many of them manuscript letters, from different European countries, mainly Italy, the Low Countries, France and Germany-Austria. The focus is on the *practice* of experimentation and its documentation, partly because I proceed from the assumption that the investigation of living nature did not necessarily entail the same type of experimentation as contemporary alchemy, pharmacy, or medicine, although all these domains of knowledge and their practitioners overlapped. The subject matter to some extent imposed its own rules. The first part of this essay analyses experimentation in the garden, which often combined practical purposes with research ones. The second and third parts discuss experimentation with both plants and animals that originated in more general questions or led to more wide-ranging conclusions about natural phenomena. The final section discusses the links with natural philosophy in these different types of experimentation in natural science, and addresses the possible implications for the concept of experimentation itself in the period shortly before the “new science” of the seventeenth century.

Keywords: natural history, natural sciences, experimentation, naturalia collecting, garden history, plant alchemy, natural philosophy.

¹ Financial support for the research lying behind this paper was kindly provided by the Netherlands Organization for Scientific Research (NWO) during successive projects based at Leiden University. I have profited from comments and questions during conferences in Bucharest, Lisbon, and Berlin, and would like to thank here in particular Peter Mason, Oana Matei, Fabrizio Baldassarri and the anonymous readers for their comments and suggestions, and Peter Mason for translations from the Latin. Unless otherwise indicated, all manuscript letters used here form part of the Clusius correspondence; the originals (which I have used) are in the University Library Leiden (further ULL), all under shelf mark VUL101; they can also be consulted online at <http://clusiuscorrespondence.huygens.knaw.nl/edition/>. All translations, except from the Latin, are my own.

1. Introduction

In 1600 two French physicians cut open one of their prize bulbs in order to find out whether the two halves would grow together again and produce flowers. During the 1580s-90s a Brussels nobleman tried out rare bulbs in his garden. He found out by testing how and where they grew best, and studied colour variation in successive generations of irises, anemones, and tulips. On Crete, in the 1590s, an Italian physician grew exotic plants from seeds that reached him via the Middle East; he noted down his observations in great detail. Slightly earlier, during the 1570s-90s, a Neapolitan apothecary dissected serpents and investigated their procreation, while the son of a Dutch fisherman opened up hundreds of fish and molluscs in the course of the 1570s-80s in order to find out more about their inner structure and reproduction.

Besides these examples, which will be discussed below, many more can be found in the manuscript letters and printed works of those who took a serious interest in living nature during the second half of the sixteenth century. I hope to show that such evidence, though apparently mundane, should be taken seriously when discussing early modern experimentation in the field of natural history, or *natural science*, as I prefer to call it here in order to emphasize the fact that we are dealing with high-quality expertise on (or just over) the brink of becoming a scientific discipline.² Throughout this essay I will use the term *experimentation*, first, because it carries overtones of practices and activities, my main focus here; second, in order to avoid the word *experiment* with its more obvious links with the modern sciences; and finally, because it is very close to the terminology used at the time.³

The cases discussed below have been selected on the basis of an intentionally very loosely defined notion of experimentation in which the key elements are a focus on living naturalia, repeated testing in practice, and some form of record keeping and documentation of results. We will look first at what this material can tell us about experimentation in natural science during the second half of the sixteenth century, and afterwards come back to the concept of experimentation itself and the possible implications of our findings.⁴ There are several reasons for following this approach. One is that the investigation of living nature did not necessarily entail the same type of experimentation as

² Obviously this is not the only possible approach. See the interesting discussion in Sorana Corneanu, Guido Giglioni, Dana Jalobeanu, "The Place of Natural History in Francis Bacon's Philosophy," *Early Science and Medicine* 17 (2012), pp. 1-10.

³ My main points of reference have been publications by William Eamon, Peter Dear, Paula Findlen, Ursula Klein, and Alisha Rankin. For detailed references, see the notes below.

⁴ My approach thus has a different starting point from that of the volume M. Veneziani (ed.), *Experientia. X Colloquio Internazionale (Roma, 4-6 gennaio 2001). Atti*, Florence: Olschki, 2002, where the words '*experientia*' and '*experimentum*' in philosophical and scientific texts guide an investigation into the articulation of the idea experimental knowledge over several centuries.

contemporary alchemy, pharmacy, or medicine – although all these domains of knowledge and their practitioners overlapped. The subject matter to some extent imposed its own rules. Early modern pharmaceutical experimentation, for instance, mainly took place in the apothecary's shop or laboratory-distillery, or nearby in the courtyard. Those who studied plants and animals often experimented outdoors, in the garden or courtyard.

At the present stage of research it seems, moreover, important to give priority to evidence from practice rather than to the use of specific terms. Words can be particularly deceptive in this case, since the terms used at the time – (French) *experimenter*, (Italian) *experimentare*, and (Latin) *experiri* and *experimentum* – refer as often to ordinary experience as to what we have come to call experimentation. How the term *experiment* could refer to a very physical experience, activity and sensations is evident, for instance, from the fossil investigations by the Flemish physician Johannes Goropius Becanus (1518-1572) discussed by Ciancio. Goropius Becanus used the term to denote his personal experience (in contrast to what he had read in the works of others), which in this case comprised his ascent of all the high mountains of the Trentino where he looked for and found fossils.⁵ Not the term as such, therefore, but only a fairly detailed description of practice can elucidate what was intended. Most sixteenth-century naturalists never unequivocally generalized their findings and only extremely rarely discussed their concepts or methods beyond a fairly general emphasis on direct observation and eye witnessing. None of this implies, however, that they were ignorant of general notions or uninterested in larger patterns. That much is evident, for instance, from diverse attempts by naturalists from the 1540s to 1610s to organize the world of plants.⁶ While some natural philosophers of the seventeenth century, such as Bacon and Descartes, explicitly engaged with the study of living nature, it is far less clear to what extent naturalists of the preceding century were influenced by natural philosophy – beyond the pervasive but often unspecific inspiration of Aristotle, Pliny, Theophrastus, Dioscorides, Galen, and other classical authors.⁷

⁵ See Luca Ciancio, “Un interlocutore fiammingo di Fracastoro: il medico Iohannes Goropius Becanus (1518-1572) e la teoria dell'origine organica dei fossili,” in Alessandro Pastore and Enrico Peruzzi (eds.), *Girolamo Fracastoro fra medicina, filosofia e scienze della natura*, Florence: Olschki, 2006, pp. 141-155: pp.148, 154.

⁶ See for botany, Brian Ogilvie, *The Science of Describing. Natural History in Renaissance Europe*, Chicago: University of Chicago Press, 2006, esp. Ch. 5; and on visual ordering in botany and zoology, see Florike Egmond, *Eye for Detail. Images of Plants and Animals in Art and Science, 1500-1630*, London: Reaktion Books, 2017, esp. Ch. 2 and 3. Specifically on Aldrovandi's and Cesi's tables of plant organization, see Andrea Ubrizsy Savoia, “Il metodo sinottico, collante tra la *Syntaxis Plantarum* di Ulisse Aldrovandi e le *Tabulae Phytosophicae* di Federico Cesi,” in Antonio Graniti (ed.), *Federico Cesi: Un principe naturalista*, Rome: Bardi Editore, 2006, pp. 525-555.

⁷ See e.g. the special issue of *Early Science and Medicine* (vol. 17, 1-2, 2012) which is largely devoted to Francis Bacon and Natural History, and there in particular Corneanu, Gigliani and

It is, in fact, rare to find clear statements concerning a natural philosophical orientation or framework in the printed works of the great naturalists of the sixteenth century such as Belon, Rondelet, Fuchs, Brunfels, Bock, Mattioli, Gessner, Dodoens, Lobel, and Clusius. And while nearly all botanical works of this century discuss the properties of plants, *explicit* declarations that connect them with, for instance, the doctrine of signatures, zodiacal patterns, or alchemical notions, are relatively rare.

A few exceptions confirm this pattern. The doctrine of signatures was, as Eamon has shown, one of the cornerstones of the Neapolitan Giambattista Della Porta's (1535-1615) theory. Precisely for that reason Della Porta was (and is) not primarily known as a naturalist, but as a natural philosopher and investigator of nature's secrets.⁸ Prince Federico Cesi (1585-1630) of the early seventeenth-century Roman Accademia dei Lincei is another rare example in which a complex and personalized natural philosophy – manifest in his notion of an *anima vegetale* (plant soul) and a belief that the categories of plants, animals and stones were not separate – demonstrably affected his investigation of living nature.⁹

2. Garden Experimentation

The Brussels nobleman Jean Boisot is a good example of the fascination with rare plants and especially bulbs that was widespread in late sixteenth-century court circles, and especially in the Habsburg courts in Brussels, Vienna, and Madrid. In a series of detailed letters Boisot informed the naturalist Carolus Clusius (1526-1609) during at least fifteen years (1582-1597) about his care for the garden, successes and losses, fascination with bulbs, and experimentation with overwintering, different soil types, and plant propagation. He grew bulbs from seed, grafted his then still quite rare horse chestnut onto a sweet chestnut tree, and had a constant interest in colour (in)stability. Boisot

Jalobeanu, "The Place of Natural History"; and Peter Anstey, "Francis Bacon and the Classification of Natural History," *Early Science and Medicine* 17 (2012), pp. 11-31. See further Fabrizio Baldassarri, *Natural History and Method in Descartes. Global Physics and Particular Bodies in Cartesian Philosophy of Nature* (forthcoming); Paula Findlen, "Francis Bacon and the reform of natural history in the seventeenth century," in Donald Kelley (ed.), *History and the Disciplines: the Reclassification of Knowledge in Early Modern Europe*, Rochester N.Y.: University of Rochester Press, 1997, pp. 239-260; and Stephen Gaukroger, *Descartes' System of Natural Philosophy*, Cambridge: Cambridge University Press, 2002. An Aristotelian approach to nature left enormous interpretative room, for instance in classifying and ordering living creatures. See esp. G. E. R. Lloyd, "The Development of Aristotle's Theory of the Classification of Animals," *Phronesis* 6 (1961), pp. 59-81.

⁸ Or "perlustratore dei secreti naturali:" see William Eamon, *Science and the secrets of nature. Books of secrets in medieval and early modern culture*, Princeton: Princeton University Press, 1994, esp. pp. 194-229, quotation at p. 195.

⁹ On Cesi, see Ubrizsy Savoia, "Il metodo sinottico;" and Luigi Guerrini, *I Trattati Naturalistici di Federico Cesi*, Rome: Accademia dei Lincei, 2006.

and several of his male and female relatives were among the early plant collectors in Europe to grow tulips, a rare and exotic plant that was first seen in Western Europe in the 1550s and began to spread rapidly in the 1570s-80s.¹⁰

Boisot uses an interesting terminology to describe bulb propagation. He writes, for instance, “this year’s tulips look very much like their mothers.”¹¹ When he received the “child” (i.e. an offset) of a double crocus from a friend, he noted: “but both the mother and the child are single this year.” His tulips “took after their parents in colour,” but other bulbs did not flower at all even though the plants were big enough and came back for four to five years; he called the latter “sterile.”¹² If a white-flowering plant reverted to another colour, or if the flowers of its “children” were not as white as those of the “parent,” Boisot uses the term “degenerate” (*forligner*):

Concerning the gladiolus with a whitish flower [...] Perhaps some of the plants that I have sent you have grown from the seeds that fell from the white ones and have *changed kind* [my emphasis], which as you know several other plants do as well, such as the completely white oriental hyacinth which also degenerates, as I have seen in four or five plants that grew out of its seeds, all of which produced blue flowers this year.¹³

This terminology suggests that Boisot imagined the propagation of bulbs in terms of human family descent, which to a sixteenth-century nobleman would have been indissolubly linked with the concept of honour, and he connects changing colour with degeneration and “changing kind.” Several contemporaries used the same terminology of human parentage. A fellow collector from the same country, Jacques Plateau (d. 1608), spoke of a white-flowering ranunculus which had produced a new young plant, “*le jeune premier*,” that had already flowered, but was still attached to the “mother” plant.¹⁴ And Clusius remarked that tulip seeds only rarely reproduced the colour of the “mother,” while observing that plants born from a white “hyacinth” usually differed in colour from the “mother” and were purplish or pale azure.¹⁵

¹⁰ No precise years are known for Boisot. Fifteen letters from Boisot to Clusius (all in ULL, see note 1 above), in French, encompass the period 1582-1597. See esp. those of 20 November 1584, 9 May 1586, 19 July 1591, and 25 June 1592.

¹¹ Letter Boisot to Clusius, 25 June 1592.

¹² Letter Boisot to Clusius, 17 May 1590.

¹³ Letter Boisot to Clusius, 19 July 1591: “Quant au gladiolus flore exalbido [...] Peutetre que aulcunes plantes de celles que je vous ay envoyees seront venues de la semence tombee des blanches et changee de sorte que scavez que font plusieurs autres plantes, comme fait pareillement l’hyacinthe orient totus niveus qui forlignie aussij comme jaij vu en quatre ou cinq plantes venue de sa semence qu’ont faictes toutes ceste annee le fleur bleux.”

¹⁴ Letter Plateau to Clusius, in French, 15 May 1596.

¹⁵ Letters Clusius to Caccini, in Italian, 1608, published in Piero Ginori Conti, *Lettere inedite di Charles de l’Escluse (Carolus Clusius) a Matteo Caccini, Floriculture Fiorentino*.

Boisot's passionate interest in colour instability in successive generations of bulbs, and the discovery of new and special colour combinations in the wild and in gardens was shared by many other garden owners and rare plant collectors of the 1570s-90s in the Low Countries, France, Germany, Italy, Austria, and Spain.¹⁶ Clusius noted that carnations, jonquils and delphiniums could not only change colour but also revert from double to single from one generation to the next, whereas the seeds of a third generation of delphiniums sometimes produced double flowers again, but in a variety of colours ranging from white to deep purple, ash-coloured and milky white. Upon testing, he had found it to be untrue, however, that carnation seed put in water with some saffron would produce pure red carnations.¹⁷

Fascination with rarity and interest in colour were inextricably connected. They quickly went beyond observation and led to active interventions and experimentation in the attempt to create new rarities by artificial colouring or by propagating tulips and other bulbs from seed. The latter process takes years but, as Clusius already noted, usually results in colour changes, unlike propagation via offsets. In 1594 Clusius instructed his friend Justus Lipsius how to sow tulips and told him that he would enjoy this experimentation (*experiri*) as much as the eventual result.¹⁸ Intentionally or not, such forms of experimentation augmented knowledge about the propagation of rare bulbs, from tulips and "hyacinths" to bulbs from the amaryllis family that were newly introduced from America in the late sixteenth century. Several decades later, in the 1630s, this passion would manifest itself in the Dutch tulip mania, which – apart from its many other aspects discussed by Goldgar – was also a manifestation of the obsession with rarity in the form of colour.¹⁹

The terminology of human parentage should set us thinking about the possible implications of the ubiquitous fascination with colour variation among sixteenth-century plant growers and naturalists.²⁰ To a modern gardener the

Contributo alla storia della botanica, Florence: Olschki, 1939, pp. 53, 56. The term hyacinth covered a wider range of plants than at present.

¹⁶ Evidence from all these countries can be found throughout the Clusius correspondence. See Florike Egmond, *The World of Carolus Clusius: Natural History in the Making, 1550-1610*, London: Pickering & Chatto, 2010.

¹⁷ Letter Clusius to Caccini, in Italian, 1608, published in Ginori Conti, *Lettere inedite*, pp. 60-63. Similar remarks can be found in the letters from Johannes van Hoghelande to Clusius (ULL), and in Clusius' printed works, e.g. in the 'Appendix Peregrinarum et Elegantium nonnullarum plantarum' of his Iberian Flora: *Rariorum aliquot stirpium per Hispanias Observatarum historia*, Antwerp: Plantin, 1576.

¹⁸ Letter of 10 August 1594, quoted in Jeanine de Landtsheer, "Justus Lipsius and Carolus Clusius, a flowering friendship," *Bulletin of the Belgian Institute* 68 (1998), pp. 273-295: p. 280.

¹⁹ Anne Goldgar, *Tulipomania: Money, Honor, and Knowledge in the Dutch Golden Age*. Chicago: University of Chicago Press, 2007.

²⁰ There are parallels with similar modern concepts, but here I focus on possible sixteenth-century meanings.

colour instability of the examples given above is no more than variation. Some sixteenth-century naturalists appear to have shared that view. Clusius spoke in 1584 of “contemplating the rich variety of shades within the same *genere* [i.e. stock, family, race] of flowers.”²¹ Others, however, seem to have regarded new colour variations and, in particular, the rare white varieties as new kinds of plants. The gardeners among them may have felt that, by experimenting with colour, they were learning how to create new plants – somewhat like advanced plant alchemy, or what Della Porta would have regarded as *natural magic*.²² Boisot almost put it into so many words when he spoke about a plant that “changed kind” in his letter quoted above. Clusius’ experimentation with saffron also shows that some had recourse to artifice when trying to create new flower colours. A Dutch friend and plantsman in Leiden, Johannes van Hoghelande, informed Clusius in 1592 that there were ways and means to create a blue-flowering “sambuco”, and methods of making plants produce double or more strongly scented flowers were certainly known at the time.²³ Nature was, therefore, by no means regarded as unalterable in these circles.

Testing in the garden in these élite circles focused not only on the transmission of colour and double-single characteristics, but also concerned many practical aspects of gardening: planting methods (pots, beds, out in the open), soil types, irrigation, drainage and humidity, acclimatization, and – in the north of Europe – overwintering.²⁴ Many examples of developing suitable locations for overwintering (in Flanders), of soil and potting experimentation in order to accommodate special bulbs (Netherlands), and of the acclimatization of plants from the high mountains to sea-level conditions (France), occur in Clusius’s correspondence with collectors-naturalists-apothecaries from all over Europe. The recurring terms used are *experimentare* and *experimenter*.²⁵

²¹ “*varietatis colorum in eodem stirpium genere*”. Letter from Clusius to Lipsius, quoted in De Landtsheer, “Justus Lipsius,” p. 278. I have intentionally *not* translated “*genere*” as genus, which would immediately suggest the modern hierarchy of biological classification, in which genus comes above species and below family.

²² Goldgar, *Tulipomania*, esp. pp. 116-118 discusses the extent to which tulips were seen as art and as man-made objects, mainly in the seventeenth and eighteenth centuries. On Della Porta and trying to influence the colour of a horse’s offspring, see Eamon, *Science and the secrets of nature*, p. 218.

²³ Hoghelande to Clusius, Latin, 12 August 1592.

²⁴ More evidence can undoubtedly be found in the agricultural treatises of this period, which I have not consulted. For a discussion of gardening and knowledge development following a more Latourian approach, and focusing on the seventeenth century, see Alette Fleischer, “Gardening Nature, Gardening Knowledge: The Parallel Activities of Stabilizing Knowledge and Gardens in the Early Modern Period,” in H. Fischer et al. (eds.), *Gardens, Knowledge and the Sciences in the Early Modern Period*, Basel: Birkhäuser, 2016, pp. 289-304.

²⁵ For instance, in the letters by Peeter van Coudenberghe (Antwerp), Christiaan Porret in Leiden, and Joachim Levenier in Bordeaux. This material is discussed in more detail in Egmond, *The World of Carolus Clusius*.

Experimentation with potting, irrigation and so on can to a certain extent be regarded as induced by practical circumstances and requirements – which, of course, in no way diminishes its importance. This was to a far lesser degree the case, however, with experimentation concerning colour transmission and double-single characteristics. There we are dealing with the manifestation of a different type of interest, rooted in the fascination with rarity and curiosity that pervaded much of sixteenth-century Europe.

Like certain alchemical experiments and astronomical practices, the latter type of experimentation and the collecting of rare naturalia in the garden formed part of what we might call spectacular science – the domain where a scientific interest in nature in the broadest sense of the term overlapped with the need for display.²⁶ It is important to note, however, that this type of science could be found not only in courts but also among a much wider circle of élite collectors. Nor should its more spectacular manifestations be seen as detracting from the expertise involved, which was not only real but could also be used for practical and non-ostentatious aims. Elector August of Saxony published a technical manual (in 1571), based on his own experience, on growing and grafting fruit trees. Landgrave Wilhelm IV of Hesse-Kassel, prince practitioner *par excellence*, conducted astronomical and mathematical experiments, but also tested poison on dogs (1580).²⁷ Grand Duke Francesco I de' Medici, who had a great interest in alchemy, is said to have invented a special preservative liquid that kept the shine and colours of dead animals intact. This allowed his court painter Jacopo Ligozzi to study them, at length, in detail and paint them “from life.”²⁸ And as Rankin and Keller have shown, many noblewomen in Europe not only experimented with rare decorative flowers, but were also personally involved in plant experimentation for medicinal purposes in the service of their extended households.²⁹

²⁶ S. Pumfrey and F. Dawbarn, “Science and patronage in England, 1570-1625. A preliminary study,” *History of Science* 42 (2004), pp. 137-188, speak of “ostentatious natural knowledge.” Cf. Paula Findlen, “Controlling the experiment: rhetoric, court patronage and the experimental method of Francesco Redi,” *History of Science* 31 (1993), pp. 35-64: pp. 45-49.

²⁷ See Alisha Rankin, “Becoming an expert practitioner. Court experimentalism and the medical skills of Anna of Saxony (1532-1585),” *Isis* 98 (2007), pp. 23-53: pp. 25, 32-33; cf. Tara Nummedal, *Alchemy and authority in the Holy Roman Empire*, Chicago: Chicago University Press, 2007, here at pp. 82-83; and Bruce Moran, “Prince-practitioner and the Direction of Medical Roles at the German Court. Maurice of Hesse-Kassel and his physicians,” in V. Nutton (ed.), *Medicine at the courts of Europe, 1500-1837*, London: Routledge, 1990, pp. 95-116.

²⁸ See Maria Elena de Luca and Marzia Faietti (eds.), *Jacopo Ligozzi 'Altro Apelle'*, Florence: Giunti Editore, 2014, pp. 36-37; and Alessandro Cecchi, Lucilla Conigliello and Marzia Faietti (eds.), *Jacopo Ligozzi 'pittore universalissimo'*, Livorno: Sillabe, 2014, pp. 48-49.

²⁹ On noblewomen, gardens and plant medicine, see Rankin, “Becoming an expert practitioner;” Lynette Hunter, “Women and domestic medicine: lady experimenters, 1570-1620,” in Lynette Hunter and Sarah Hutton (eds.), *Women, science and medicine: mothers and sisters of the Royal Society, 1500-1800*, Phoenix Mill: Sutton, 1997, pp. 89-107; and Katrin

The garden experimentation discussed so far could be found all over Western Europe during the second half of the sixteenth century. It was no incidental activity, but formed an integral and ongoing aspect of expert gardening. It required close observation as well as some form of notation. The gardens of many European plant collectors and naturalists can indeed be regarded as experimental gardens: outdoor laboratories and living collections at the same time. The garden as setting for experimentation was to a certain extent controlled. Its location, general climate, soil type, drainage, light, prevailing winds, and shade did not change fundamentally, but could be modified to a limited extent by the gardeners' efforts. Some, perhaps most, expert gardeners-naturalists noted down and compared their results and findings over a long series of consecutive years (from five to twenty years or more), as indeed is evident from the letters and plant lists sent to Clusius from all over Europe. Notebooks or garden diaries probably functioned as both annual inventory lists of the garden and records of experimentation.

None of the garden experimentation described thus far seems to have been undertaken *in order* to establish more general patterns in living nature, whatever the social or educational background of those involved. The garden experimentation by Clusius, erudite naturalist and university trained humanist, did not differ in either character or scope from that of a plantsman-apothecary or a member of the court nobility, neither of whom had Latin or university training. Practical considerations and curiosity stimulated by rarity predominated. No clear influence of natural philosophy can be established, but experimentation did sometimes lead to generalization of observations. Implicitly, the strong interest in colour variation and the terminology of human parentage hint at early modern concepts of genus, species and propagation. Traces can also be discerned of the notion that Nature played with colour, and that the gardener could imitate Nature and attempt to create new plants.

3. Botanical Experimentation

Other kinds of plant experimentation in this same period originated in more general questions or led to more wide-ranging conclusions about natural phenomena. Examples are much harder to find, however. The following ones concern university-trained physicians with an international orientation, great expertise in *materia medica classica*, and an explicit interest in the medicinal effects of plants.

Onorio Belli (1550–1604), a physician from Vicenza, lived on Crete for most of the 1580s and 1590s. Most of Belli's botanical work concentrated on the description and identification of the wild flora of Crete, of which he was

probably the first to undertake a systematic survey.³⁰ His garden experimentation with exotic plants that reached him from or via Egypt and the Middle East led to the observation and description of some curious phenomena. In 1594-95 Belli received a fruit of the baobab (or abavo) tree from Cairo that had earlier come from a port in Eritrea. In the summer of 1595 he planted the seeds from this fruit, which sprouted and soon reached the height of 1.5 feet. The young plants that he transferred to his garden (*viridarium*) in March of the next year died, however, from lack of water and the gardeners' negligence. Four young plants which he kept in big pots in his house survived.

They all had tuberous roots, (...) which seemed to me a very great wonder of nature. But the ones that I keep in the house only produced leaves around the solstice, that is around the beginning of July, but so different that nobody who had seen the plants last year and did not know that they came from a single fruit would ever have considered that these trees are congeneric.³¹

Though Belli also describes the roots, colour, taste, and change over time of the young baobab plants, his attention was drawn in particular by the strange phenomenon of the different leaves, of which he provides a very detailed description. The first of the four young plants had somewhat serrate leaves, similar to those of the horse chestnut, but with different numbers of leaflets – from one to three – attached to each petiole. The second plant's leaves were hardly serrate at all, and had two to three leaflets per petiole. The third plant was similar, but with five leaflets per petiole, and the fourth had a single, very short and hardly serrate leaf that looked rather like those of the *malus citriu* (lime). Belli not merely observed but also drew conclusions, and it is important to keep in mind that he had never seen a full-grown baobab. He suspected “that different types of Abavo trees are produced by this fruit,” and hoped that more plants would sprout that could confirm this suspicion.³² Belli's reasoning thus must have gone as follows: seeds from one and the same fruit result in young trees with different kinds of leaves which resemble different kinds of European trees; therefore one fruit can bring forth different kinds of trees.

³⁰ On Belli, including a fuller and annotated Latin edition of Belli's letters, see Luigi Beschi, *Onorio Belli Accademico Olimpico. Scritti d' Antiquaria e Botanica 1586-1602*, Rome: Viella, 2000; cf. Egmond, *The World of Carolus Clusius*, pp. 85-88.

³¹ Beschi, *Onorio Belli*, pp. 223-245: transcription of Belli's letters to Clusius (in Latin, from Crete; originals in the Ambrosiana Library, Milan) of 15 February and 15 August 1596, quotation from the August letter at p. 235: “Hae omnes radice constabant tuberosa, [...] quod maximum mihi naturae miraculum visum est. Sed illae quas domi servo circa Solstitium tantum folia emiserunt, hoc est, circa principium mensis Iulii, sed ita diversa, ut nemo, qui plantas anno praeterito viderit, ignarusque fuerit ex unico fructu satas fuisse, nunquam congenere eas arbores esse iudicabit.” Belli's letter-report of 15 August 1596 was published by Clusius in his *Rariorum plantarum historia*, Antwerp: Plantin, 1601, pp. ccxcix-cccxiv.

³² Belli to Clusius, 15 February 1596, as quoted in Beschi, pp. 234-245, here at p. 235: “ita affirmare possumus Abavi arbores diversorum generum inveniri.”

Belli's observation of another phenomenon, now known as a particular form of heliotropism, resulted in one of its very early descriptions. It concerned a plant that he called "Bean from Jemen" or "Abrus according to Alpini" (presumably *Abrus precatorius*).

They turn so that they face the sun: for the leaves which are pinnate [...] are very closely pressed together by sunset on the part that is turned away [i.e. from the sun], so that the points of the leaves face the ground, and the long *pediculi* to which the leaves are attached bend towards the earth during the night, so that they just touch the stalk, and remain like this all night; and when the sun rises they open up and the *pediculi* turn themselves on their spot almost at right angles from the stalk. By midday the leaves gradually start to face the sky, and during the later part of the afternoon they in their turn close very tightly together, so tightly that the one touches the other, and the tips [of the leaves] face the sky in exactly the opposite way to what they did during the night; afterwards they open up when the sun goes down. This periodical turning around of the leaves to the sun I regard as wonderful and worthy of observation, and on that account I thought it of particular significance for you.³³

Belli's reasoning thus started in each case from highly detailed and repeated observations, which he subsequently summarized in descriptions that covered a long span of time. He then tried to infer a more general rule from his specific case, and recognized that the plant movements of his Jemen bean belonged to a phenomenon that linked plants to the sun. Neither Belli nor Clusius (who published Belli's observations) went any further: neither, for instance, questioned Aristotle's division between plants and animals on the basis of this particular plant's movements.

In the 1590s Tobias Roels (d. 1602?), a young town physician in the Dutch Republic, shared many of Belli's interests as well as a collegial friendship with Clusius. Roels combined considerable plant expertise, a great interest in exotic naturalia, and excellent access to the latter via the ships that arrived from far-away continents in his port town Middelburg. Clusius published Roels's long report in Latin (dated 1597) on exotic naturalia, in which the latter discusses the differences between manioc and yam, how to extract the poisonous juices from manioc, the qualities of palm oil, and many other topics. It is special not merely in terms of subject matter, but also for the sources that Roels explicitly mentions, which highlight the value he attached to direct experience and first-hand evidence. He had questioned Dutch merchants and apothecaries who had been in contact with exotic naturalia, but also "Indians," twelve

³³ Belli to Clusius in Latin, 15 August 1596, quoted in Beschi, *Onorio Belli*, here at p. 244. This is an early description of such plant movements judging from C. Webster, "The Recognition of Plant Sensitivity by English botanists in the seventeenth Century," *Isis* 57 (1966), pp. 5-23.

black slaves from São Tomé off the African West Coast (who formed part of the Dutch household of an official who had been to the East Indies), a sailor who had been imprisoned for three years on the island Hispaniola, and a Portuguese surgeon from the same island who knew New World nature from personal observation.³⁴

Like Belli, Roels never saw the full-grown, live plants: his observations were limited to fruits, seeds, a piece of yam root, some palm oil, a powder, et cetera. Those fragments and pieces clearly triggered questions in his mind that led to experimentation. He sent two coconuts to Clusius that had begun to sprout during the sea voyage to Europe. Roels had removed the hard shell of one of these in order to show how the sprout and roots developed. He kept a third coconut, eventually opened it, and discovered that the liquid had disappeared and that a sprout had grown from the “marrow” (*merg*) and emerged from the third hole in the hairy shell of the nut. It soon emitted five to six roots. Roels describes in minute detail the sprout’s shape, the beginning of its folded leaf, and so on, but he did not try to grow the plant in a pot, since he imagined that it would soon die in the Dutch climate.

Roels’s report contains an intriguing digression, inserted at the end of his description of palm fruit and oil from São Tomé, where he ponders wider questions evoked by his experience with the exotic naturalia.

Had I not feared to exceed the limits of a letter, I would like to raise a question that occurred to me while I was writing: why does oil float on water? Some say that bodies sink if heavy and float if light. That bodies do not sink because of their heaviness or float because of their lightness, however, but find their level depending on the proportion and preponderance of their constituent elements, is shown by the fact that a small stone sinks in a river on account of its earthy and compact substance, while a large piece of wood remains afloat on account of its airy and porous substance. But I leave these matters aside and return to the oil of *caryoces*.³⁵

Like Belli’s fascination with plant movements and the baobab’s strange leaves, Roels’s curiosity about oil and water had no practical purpose, but addressed more general natural phenomena. The fact that Roels almost apologized for this

³⁴ Roels’s original letter-report of 8 May 1597 no longer exists, but the full text was published by Clusius in his *Rariorum plantarum historia*, pp. Cccxv-cccxx. For more on Roels, see Egmond, *The World of Carolus Clusius*, esp. pp. 141-152.

³⁵ Clusius, *Rariorum plantarum historia*, p. cccxviii: “Nisi vererer epistolae limites nimis excedere, moverem quaestionem, quae inter scribendum occurrebat: Cur nimirum oleum in aqua supernatet? dicunt aliqui corpora ob gravitatem submergi, & ob levitatem natere. Quod autem corpora non ponderis aut levitatis ratione natent, vel subsideant, sed pro elementorum, ex quibus constant, proportione & dominio, locum inter elementa petant: parvus scrupulus in flumine ostendit, qui ob terream & compactam lapidis substantia subsidet: in quo ingens trabs lignea, ob aëream ejus & porosam substantiam supernatat. Sed his praeteritis ad oleum Caryoces revertor.”

digression is intriguing in itself. His reference to the stylistic form of the letter opens the possibility, however, that these issues belonged, in his mind, to another genre of knowledge – that of natural philosophy – which could exist next to the narrative of observation and experiment in which he was engaged here.³⁶

This same inquisitive mentality characterized the French physicians in Poitiers mentioned at the beginning of this essay. François de Saint-Verturnien (c. 1540–1607) was not only an erudite humanist and close friend of Scaliger, but had studied medicine in Montpellier and was a passionate gardener. In 1600 Vertunien and his son-in-law and fellow physician cut in half the bulb of a precious crown imperial and put the two halves back together in the soil – purely, it seems, for the sake of scientific curiosity. In the course of the summer only one flower stalk developed. They dug up the bulb again, in the autumn, to inspect to what extent the two halves had grown together, and found that the halves were indeed re-joined and had produced six small bulbs the size of nuts, grouped around the big bulb and attached to it by long fibres.³⁷ It may well be that their professional background inspired them to experiment with plants in a way that is reminiscent of human and animal dissections and inspections. If so, their description is a rare report of botanical experimentation by means of anatomical methods. The concept of botanical anatomy was certainly known by this time: a manuscript album of 1583 with nature prints of plants and comparative drawings of plant parts by the German physician Theophilus Kentmann (1552–1610) bears the title *Botanatomia*.³⁸

4. Experimentation with Animals

The erudite naturalist-pharmacist Ferrante Imperato (c. 1525–c. 1615) is now primarily remembered for his impressive museum in Naples with its collection of stones, minerals, animals, and living and dried plants, and for his *Dell' Historia Naturale* (Naples: C. Vitale, 1599). This work goes far beyond the requirements of pharmacy and discusses, besides plants and animals, physical geography, geology, meteorology, optics, soil types and their uses, fire,

³⁶ It is hard to believe the reason that Roels gives (length of letter), since a) Clusius had clearly *asked* Roels for information on exotics, and b) this letter-report has the amazing length of almost six large and densely printed pages, and was published almost verbatim by Clusius. Perhaps we are dealing here with a forerunner of the “experimental narrative”, that was developed, as Findlen has argued, by Francesco Redi in the late 17th century; see Findlen, “Controlling the experiment,” p. 44.

³⁷ Vertunien to Clusius, in French, 10 April 1601.

³⁸ Theophilus was a physician in Meissen and the son of naturalist-physician Johannes Kentmann, a close friend of Conrad Gessner. Theophilus’ manuscript has some 180 folios and together with his father’s naturalia drawings forms the *Codex Kentmanus*, Herzogin Anna Amalia Bibliothek, Weimar, Fol 323.

minerals, the wind, metals, the colour of water, et cetera.³⁹ Imperato's research practice shows similarities to that of various other erudite apothecaries in other parts of Europe, and can as such be regarded as part of the increasingly experimental character of early modern medicine.⁴⁰ It also belonged, however, as Stendardo has pointed out, to a specifically Neapolitan tradition of artisanal science with an emphasis on collaboration between physicians and *aromatari* that contrasted strongly with the tradition of Padua, where *medicina filosofica* predominated over "the art of the apothecaries."⁴¹ Neapolitan artisanal science is epitomized by the mid sixteenth-century Accademia dei Segreti of Girolamo Ruscelli with its goal of experimental research, union of scholars and craftsmen, and strong participation of apothecaries, herbalists, alchemists and gardeners in particular. According to Eamon and Paheau, the goal of this Accademia was to try out and prove recipes and secrets, which Ruscelli saw as "a deliberate application of an experimental method;" each recipe had to be "proven three times before it could be accepted as trustworthy."⁴²

Imperato's research practice also demonstrates that late sixteenth-century experimentation could assume a modern-looking *format* (hypothesis, repeated testing, general conclusions about natural phenomena) even though it originated in a utilitarian question that was deeply rooted in ancient history. An example described in 1573 focuses on the reproduction of reptiles, but originated in the practical context of producing medicines. Vipers were an important ingredient in the preparation of theriac, a composite wonder-medicine dating back to classical antiquity; its composition formed a major point of debate in the sixteenth-century medical world. Careful to follow Galen's instructions and use a non-pregnant female viper, Imperato always dissected the vipers he was planning to use and always found eggs in them, whatever the season. His interest in whether these creatures were oviparous or viviparous led him to experiment with a live

³⁹ Antonio Neviani, "Ferrante Imperato. Speciale e naturalista Napolitano con documenti inediti," *Atti e memorie dell'Accademia di Storia dell'Arte Sanitaria* II, 2, (1936), pp. 57-74, 124-145, 191-210, 242-267; Erica Stendardo, *Ferrante Imperato: collezionismo e studio della natura a Napoli tra Cinque e Seicento*, Naples: Accademia Pontaniana, 2001; and Paula Findlen, *Possessing nature: museums, collecting and scientific culture in early modern Italy*, Berkeley: University of California Press, 1994, esp. pp. 225-232.

⁴⁰ On the shift from a textually to an experimentally based natural science as part of a broader dispute about the location of authority, see S. Pumfrey, "The history of science and the Renaissance science of history," in S. Pumfrey, P. L. Rossi and M. Slawinski (eds.), *Science, Culture and Popular Belief in Renaissance Europe*, Manchester: Manchester University Press, 1991, pp. 48-70.

⁴¹ Stendardo, *Ferrante Imperato*, p. 28.

⁴² See William Eamon and Françoise Paheau, "The accademia segreta of Girolamo Ruscelli. A sixteenth-century Italian scientific society," *Isis* 75 (1984), pp. 327-342: p. 333. On the Neapolitan tradition see also Stendardo, *Ferrante Imperato*; and Gabriella Belloni Speciale, "La ricerca botanica dei Lincei a Napoli. Corrispondenti e luoghi," in F. Lomonaco and M. Torrini (eds.), *Galileo a Napoli*, Naples: Guida, 1987, pp. 59-79.

viper, which he put “in a box of convenient size, with a purpose-made lid constructed of metal netting, in which I have had it permanently spied, night and day, in order to observe how and when it gave birth.” The result was a detailed description of the live birth of the young serpents, curled up in a transparent membrane; they started moving and liberating themselves as soon as they saw daylight.⁴³ Imperato’s original interest in the viper’s pregnancy was medicinal, therefore, and inspired by the classical tradition. The outcome was new knowledge of nature (the viviparous nature of some serpents) obtained by dissection, repeated experimentation, long-term observation, and comparison. Phrased differently, Imperato’s research question was the result of his looking back to ancient history, but it carried the researcher in new directions in terms of both content, questions and methodology.

A brief parallel can be drawn with early sixteenth-century anatomy. In his illuminating discussion of the pre-Vesalian surgeon-anatomist Jacopo Berengario da Carpi (c. 1460-c. 1530), Roger French has emphasized that Berengario’s training in practice (followed by university training only *after* he had already become an experienced surgeon) is likely to have deeply influenced his later emphasis on the “senses of sight and touch in anatomy, his rejection of purely verbal demonstration of structure and his admiration for anatomists who were *artificers*, craftsmen” who worked with eye and hand.⁴⁴ As a result of repeated experimentation undertaken specifically in order to confirm or disprove the opinions of great medical authorities (such as Galen and Avicenna), Berengario found himself repeatedly in clear disagreement with those authorities: “For Berengario the ultimate use of demonstration as proof was in the form of sensory experience that we call experiment.”⁴⁵ Yet, French explicitly does not lift Berengario out of his context of scholastic anatomy and into a “new methodology based on sense perception.” Indeed, French sees the latter as an integral part of the Commentary form in which Berengario addresses contemporary academics in their own terms. He argues that Berengario saw himself as forming part of *their* science, and coins the term “practical logic” for the ways in which Berengario sought to substantiate his conclusions.⁴⁶

Not everyone in late sixteenth-century Naples followed the pragmatic, intellectual tradition rooted in artisanal practices. The differences between Imperato’s practice-based expertise and, for instance, his fellow citizen Giovanni Battista Della Porta’s more philosophically oriented experimentation and investigation of nature’s secrets are well known, as are the differences in their

⁴³ See Neviani, “Ferrante Imperato,” pp. 136-137, and quoting Imperato’s description (1573) on pp. 247-248.

⁴⁴ Roger French, “Berengario da Carpi and the use of commentary in anatomical teaching,” in Andrew Wear, R.K. French and I.M. Lonie (eds.), *The medical Renaissance of the sixteenth century*, Cambridge: Cambridge University Press, 1985, pp. 42-74: p. 44, cf. pp. 48 and 57.

⁴⁵ French, “Berengario,” pp. 52-53, and see pp. 52-61 for various forms of testing.

⁴⁶ French, “Berengario,” p. 52.

social status.⁴⁷ The distinctions did not run along clear-cut lines, however, in which experimentation and a more general natural philosophy could be found on one side, and a more scholastic approach in an Aristotelian context on the other. Imperato's experimentation appears to have been directed at a more general understanding of natural phenomena, but it was not (or not clearly) connected with an explicit natural philosophy. Della Porta, as Eamon argues, had little interest in testing general hypotheses, but his experimentation formed part of a lifelong project to investigate the secrets of nature. That project fitted within his personal natural philosophy which blended "Aristotelian physics, Renaissance Neo-Platonism, naturalistic metaphysics in the tradition of Telesio, and a poetic fancy mainly his own."⁴⁸ Certainly, neither was a kind of proto-Bacon.⁴⁹

The Neapolitan evidence on these forms of experimentation suggests intriguing but as yet only partially explored connections between local traditions, combinations of socio-economic and cultural circumstances, and particular scientific approaches. It may not be a coincidence that Imperato in Naples (c. 1570-1610), Roels in Middelburg (1590s-early 1600s), and the experimental naturalists of Lime Street in London (1590s-early 1600s), discussed especially by Harkness, shared a tendency to pragmatic but generalizing experimentation with virtually no attention to natural philosophy, on the one hand, and were located in urban settings with excellent access to foreign naturalia and strong traditions of practitioners, on the other hand.⁵⁰

The experimentation of the Dutchman Adriaen Coenen (1514-1587) during the 1560s-80s deserves some further attention here precisely for this reason. Coenen was a wholesale fish merchant and auctioneer, and a dealer in marine rarities who described himself as driven by an insatiable and lifelong curiosity about living nature.⁵¹ In his manuscript albums of the 1570s-80s Coenen

⁴⁷ Eamon and Paheau, "The Accademia Segreta"; Findlen, *Possessing Nature*, esp. pp. 226-230; Stendardo, *Ferrante Imperato*, esp. pp. 23-33, 51-65; and Giuseppe Olmi, "La colonia Lincea di Napoli," in Lomonaco and Torrini (eds.), *Galileo a Napoli*, pp. 23-59.

⁴⁸ Eamon, *Science and the secrets of nature*, p. 211 (quotation) and p. 221.

⁴⁹ *Ibid.*, (about Della Porta), p. 216.

⁵⁰ Important works contextualizing scientific approaches are, for instance: for the Lime street naturalists, their experimentation and reluctance to enter the domain of natural philosophy, Deborah Harkness, *The Jewel House. Elizabethan London and the Scientific Revolution*, New Haven and London: Yale University Press, 2007, esp. pp. 37-38, 42-43; and for the Dutch Republic esp. Harold Cook, *Matters of Exchange. Commerce, medicine, and science in the Dutch Golden Age*, New Haven and London: Yale University Press, 2007. On "hands-on" and artisanal knowledge, see esp. Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600*, Corvallis: Oregon State University Press, 2011; and Pamela Smith, *The Body of the Artisan. Art and Experience in the Scientific Revolution*, Chicago: Chicago University Press, 2004 (cf. note 59 below).

⁵¹ Adriaen Coenen, *Visboeck* (1577-81) manuscript, c. 400 folios, Koninklijke Bibliotheek, The Hague, Ms 78 E 54, f. 398 (orig. 396).

depicted and wrote down his knowledge of aquatic animals. A large part of it was based on personal observation, lifelong experience and the information from his peers and fellow villagers on the Dutch coast. He collected further information from (vernacular) publications on natural history, such as the mid sixteenth-century works on aquatic creatures by Rondelet, Belon and Gessner as well as older sources which incorporated classical and medieval knowledge.⁵²

Coenen had no Latin, and indeed no formal education beyond village school level. Given his background, education, local setting and work in the fish trade, it is likely that his step from curiosity and outdoors observation to long term eye-witnessing, documentation, and experimentation was quite personal. Since his youth he noted down memorable events and naturalia in a “memory booklet” (*memorijboeckxken*).⁵³ Coenen opened up hundreds to thousands of fish and many sea mammals every year for commercial purposes, but it is typical that he also opened up and investigated many creatures for no other reason than to satisfy his thirst for knowledge. Every year, he examined the metamorphosis from caterpillar to butterfly, sometimes in the small “writing room” in his home, where he used to carry bundles of twigs with silky cocoons. He also carefully opened cocoons, noting that some pupae had indeed been transformed into the shape of a butterfly, but had remained imperfect. The metamorphosis from frog’s egg to tadpoles with tails to frogs without tails was familiar territory as well.⁵⁴

From both personal practice and the transmitted experience of local fishermen Coenen knew about fish eggs, spawning seasons, and the sexual organs and mating habits of warm-blooded sea mammals. Like most early modern naturalists Coenen was interested in the investigation of where and how life originated – a topic intimately linked with the issues of spontaneous generation and metamorphosis that had been (and continued to be) much debated for centuries.⁵⁵ His observations comprised the whole range from ordinary fish to worms in water, beer, cheese and so on, and to marine creatures such as “sea grapes” and “sea hands” that seemed to be both animal and plant. Coenen connected worms in rotting meat or fish with the flies that arrived to feast on it, but he thought it was their excrement (and not their eggs) that turned into maggots. He tried to test this connection between flies and maggots by making sure that

⁵² Coenen’s main legacy consists of the *Visboeck* (see note above) and the *Walvisboeck* (c. 1584-1585), Erfgoedbibliotheek Hendrik Conscience, Antwerp, Ms 392. See *The Whale Book. Whales and other marine animals as described by Adriaen Coenen in 1585*, edited by Florike Egmond and Peter Mason, London: Reaktion Books, 2003; and Florike Egmond, *Het Visboeck. De wereld volgens Adriaen Coenen*. Zutphen: Walburg Pers, 2005.

⁵³ Coenen, *Visboeck*, f. 407.

⁵⁴ Coenen, *Visboeck*, f. 223v, f. 295.

⁵⁵ E.g. Marc Ratcliff, *The Quest for the Invisible. Microscopy in the Enlightenment*, Aldershot: Ashgate, 2009, esp. pp. 38-40; and Pascal Duris, “L’introuvable révolution scientifique. Francesco Redi et la génération spontanée,” *Annals of Science* 67 (2010), pp. 431-55; pp. 434-436.

no flies could reach the meat; even so, living worms emerged within three days when it was hot.⁵⁶ Coenen's investigations spanned decades and also reached *into* physical matter. He opened goose barnacle shells, noted the resemblance of the feathery mass inside to unhatched small birds, and pointed out how these differed from fish eggs. He looked inside and underneath jellyfish, and observed that ray eggs were yellow inside the fish, but black once outside in the sea. In spring clusters of eggs could be found in rays, almost identical to the egg clusters in hens, as he points out, but without shells or leathery cases. A century later, the notoriously pragmatic and non-philosophical Dutch microscopist Antoni van Leeuwenhoek studied the eggs and minuscule larvae of oysters, periwinkles, mussels and various other kinds of molluscs with similar questions in mind concerning the origins of life. Both Leeuwenhoek and Coenen concluded that they did not generate spontaneously, but the latter did not generalize his findings or argue against spontaneous generation.⁵⁷

Belli, Roels, Coenen and Imperato came from quite different social and educational backgrounds. Yet, all four experimented in order to satisfy their curiosity about natural phenomena, and regarded observation and practical experience as conclusive, even when learned physicians, classical authorities or philosophers believed and wrote differently. In all four of these cases, their professional training and practice involved the senses (ocular inspection, manual dissection, tasting, smell) and informed their experimentation. Although none aimed for an experimental natural philosophy, they were not so far removed in either subject matter or approach from Francesco Redi (1626-1697), the Tuscan court naturalist also known as one of the pioneers of the controlled experiment almost a century later.⁵⁸

5. *Experimentation, Practice, Natural Science, Natural Philosophy*

As was perhaps only to be expected, more than one type of experimentation could be found in sixteenth-century natural science. I have grouped the examples above in two main categories on the basis not of subject matter or procedure, but of motivation and scope or purpose. The first category

⁵⁶ Coenen, *Visboeck*, f. 311r, f. 313r.

⁵⁷ Coenen, *Visboeck*, e.g. f. 113r-113v, 124v. See the detailed observations in *Anthoni van Leeuwenhoek, Alle de brieven, Deel 11*: 1695-1696, ed. by L. C. Palm, Lisse: Swetz & Zeitlinger, 1983. His background as draper and lens maker is well known. See Lesley Robertson et. al., *Antoni van Leeuwenhoek, Master of the Minuscule*, Leiden: Brill, 2016.

⁵⁸ Redi's experimentalism of the 1660s-70s has been analysed by Findlen, "Controlling the experiment"; cf. Marco Beretta, "At the Source of Western Science: The Organization of Experimentalism at the Accademia del Cimento (1657-1667)," *Notes and Records of the Royal Society of London* 54 (2000), pp. 131-151. Whether Coenen's expertise belongs to the forms of artisanal knowledge discussed by Pamela Smith and Pamela Long (cf. note 50 above and note 59 below) needs to be examined further.

originated in the practical demands of gardening at the level of botanical collectors who dealt with rare and exotic plants. It resulted in expert practical knowledge, but also led to more general observations, while hinting at notions of plant descent and contemporary concepts of genus and species. Some of this experimentation carried overtones of plant alchemy and formed part of spectacular science. Those involved belonged to two fairly distinct social spheres: aristocracy, court circles and similar ranks in the church, on the one hand; and the professional circles of physicians and apothecaries, who generally came from the middle to upper bourgeoisie and the lower nobility, on the other hand.

Scientific curiosity constituted an important driving force in the second category, where experimentation was linked with wider issues of natural science, such as plant descent and propagation, spontaneous generation, metamorphosis, the movement of plants, and the distinctions between plants and animals. Often that link was implicit and needed to be teased out from detailed descriptions, repetition of tests, and so on. That implicit nature should not, I suggest, be taken for a lack of interest in wider questions, but seen as a characteristic trait belonging to a genre of nature knowledge and description typical of the sixteenth century, which was rarely explicit about any aspect of its methodology but focused on results, and relegated issues of natural philosophy to different types of reportage. Here we come up against the self-imposed boundaries of the *genre* of sixteenth-century *natural history* writing, which should not be mistaken for the mental limitations of the naturalists.

Interestingly, this second group of experimenters comprised university-trained physicians, an apothecary and a fish merchant. The number of examples is clearly too small to generalize, but this diversity does suggest that this type of experimentation can *not* be linked with any certainty to one particular professional-educational category or type of knowledge – whether of university-trained physicians, practical experts from an artisanal background (for whose knowledge the term artisanal epistemology has been suggested), or “hybrid experts”, as Klein has called those who “possessed both ‘knowledge’ and ‘skill.’”⁵⁹ This does not, however, invalidate a suggestive connection that has emerged here between a particular type of experimentation (triggered by

⁵⁹ Ursula Klein, “The Laboratory challenge. Some revisions of the standard view of early modern experimentation,” *Isis* 99 (2008), pp. 769-782: p. 780. Klein and Rankin, linking up with the more general argument of Pamela Smith about handiwork, have pointed to the large zone in which artisanal categories of practice-based knowledge (*artisanal epistemology*) coexisted with expertise based on a mixture of highly skilled handiwork and experience with field-specific, often technical education, such as painting, engineering, mining, pharmacy, etc., but where one practice is not the same as another. See also Rankin, “Becoming an expert practitioner,” Smith, *The Body of the Artisan*; and cf. Lissa Roberts, Simon Schaffer, and Peter Dear (eds.), *The mindful hand. Inquiry and invention from the late Renaissance to early industrialisation*, Amsterdam: KNAW-EDITA, 2007; and Pumfrey, Rossi and Slawinski (eds.), *Science, Culture and Popular Belief*.

scientific curiosity but without the ambition to construct a natural philosophy) and urban social settings characterized by strong artisanal traditions and special access to interesting naturalia. That link deserves to be explored further for the whole of the early modern period.

Neither of the two categories of sixteenth-century experimentation discussed here resulted in statements about “laws” of nature or attempts to develop more encompassing natural philosophies, and this fits in well with the general absence of natural philosophical statements in publications by naturalists of this century. What should we conclude from this? In part, this absence seems to be the result of sixteenth-century *genre* conventions mentioned earlier, and not of intellectual limitations. Whether the choice itself to rarely go into issues of methodology and philosophy can be connected with the general research agenda of natural science in this period, which gave priority to other matters, must remain an open question here.⁶⁰ It has often been argued that science only becomes “real science” if suffused by conceptions of a higher, more abstract kind, which are usually called natural philosophy or theory. Eamon and Paheau have called the experimentation of Rucelli’s Accademia a “stage in the development of the concept of experiment that stands midway between the medieval concept of *experimenta* as ordinary experience and Galileo’s method of using an experiment to test a hypothesis.”⁶¹ Similarly, Rankin locates court experimentalism (mainly with medicinal plants, and by noblewomen) between the medieval idea of *experimentum* and the search for universal truths of seventeenth-century natural philosophy. She argues that court experimentalism neither resembled nor influenced experimental science of the seventeenth century, since it lacked universalizing principles or an underlying natural philosophy and manifested no particular interest in a broader system of nature or in causality, but presented an empirical method without theoretical explanation.⁶²

Those conclusions are unsatisfying, because there seems to be a logical loop in defining sixteenth-century activities in terms of (an absence of) seventeenth-century characteristics. Moreover, they project a hierarchical distinction between scientific theory and practice that has become a hallmark of seventeenth-century science in historiography back into the sixteenth century.

⁶⁰ See Ogilvie, *The Science of Describing*; Egmond, *The World of Carolus Clusius*; and esp. Richard Palmer, “Medical Botany in Northern Italy in the Renaissance,” *Journal of the Royal Society of Medicine* 78 (1985), pp. 149-157. Elsewhere I have focused on observation as an aspect of sixteenth-century naturalists’ methodology. See Florike Egmond: “Observing nature. The correspondence network of Carolus Clusius,” in Dirk van Miert (ed.), *Communicating Observations in Early Modern Letters, 1500-1575. Epistolography and Epistemology in the Age of the Scientific Revolution* [Warburg Institute Colloquia 23], London/Turin: Nino Aragno Editore (2013), pp. 43-72.

⁶¹ Eamon and Paheau, “The accademia segreta,” p. 333; cf. Belloni Speciale, “La ricerca botanica.”

⁶² Rankin, “Becoming an expert practitioner,” here pp. 52-53. Cf. Michael Ben Chaim, *Experimental Philosophy and the Birth of Empirical Science*, Aldershot: Ashgate, 2004.

Something similar has happened in the historiography of organizational models of scientific activity, and there is a clear link between the two subjects. The formation of the first scientific academies – the Roman Lincei (1603-1629), the Florentine Accademia del Cimento (from 1657) and the Royal Society of London (from 1660) – and their relation with experimental philosophy has long drawn far more attention than the more loosely structured, informal forms of exchange and interaction of the sixteenth century. It would be limiting to qualify the sixteenth-century networks mainly in terms of what they may have contributed to the later academies. It is similarly limiting to look at the complex subject of sixteenth-century nature study, its methods, goals, and natural philosophy with mainly seventeenth-century criteria in mind. Klein has sought a way out of this conundrum. She argues that “early modern experimentation was by no means a unified philosophical enterprise; it was not merely the result of a transformation of a philosophical, or scholarly, tradition”, and she proposes that a “second tradition of experimentation began to flourish in the seventeenth century (...) that was tied to and developed in laboratories, artisanal and academic.”⁶³

It might therefore be fruitful to step away, at least temporarily, from the developmental perspective. As the cases discussed above have shown, sixteenth-century experimentation with naturalia could at the same time be closely linked with practical experience and take the form of repeated testing of an explicit or implicit hypothesis. It could also be both highly pragmatic and inspired by classical antiquity or subsumed in esoteric philosophy. Instead of investigating what sixteenth-century natural science and experimentation contributed to the “new” science of the seventeenth century, it might be challenging to further explore the coexistence and mutual influences of various modes of experimentation in *both* the sixteenth and the seventeenth centuries, and to study these in their specific cultural and socio-political settings. Not everyone active in seventeenth-century science was a “new” scientist or natural philosopher, after all. In spite of the vast debate on the “scientific revolution” and the concept of “science” itself, there is, moreover, still need for a continuing critical examination of the construction of a particularly influential notion of science in the seventeenth century and of the extent to which *natural* science in both the sixteenth and seventeenth centuries actually fitted that model.⁶⁴ In that context it is important to reconsider not only the differences but also the similarities between plural forms of natural science in these centuries. The continuities between the sixteenth and seventeenth centuries – rather blocked from view by the emphasis on the emergence of a “new” science after 1600 – might well be illuminating.

⁶³ Klein, “The Laboratory challenge,” p. 782.

⁶⁴ For an excellent discussion, see Peter Dear, “Towards a genealogy of modern science,” in Roberts, Schaffer, and Dear (eds.), *The mindful hand*, pp. 431-441.

Works Cited:

- Peter Anstey, "Francis Bacon and the Classification of Natural History," *Early Science and Medicine* 17 (2012), pp. 11-31.
- Fabrizio Baldassarri, *Natural History and Method in Descartes. Global Physics and Particular Bodies in Cartesian Philosophy of Nature* (forthcoming).
- Gabriella Belloni Speciale, "La ricerca botanica dei Lincei a Napoli. Corrispondenti e luoghi," in F. Lomonaco and M. Torrini (eds.), *Galileo a Napoli*, Naples: Guida, 1987, pp. 59-79.
- Michael Ben Chaim, *Experimental Philosophy and the Birth of Empirical Science*, Aldershot: Ashgate, 2004.
- Marco Beretta, "At the Source of Western Science: The Organization of Experimentalism at the Accademia del Cimento (1657-1667)," *Notes and Records of the Royal Society of London* 54 (2000), pp. 131-151.
- Luigi Beschi, *Onorio Belli Accademico Olimpico. Scritti d' Antiquaria e Botanica 1586-1602*, Rome: Viella, 2000.
- Alessandro Cecchi, Lucilla Conigliello and Marzia Faietti (eds.), *Jacopo Ligozzi 'pittore universalissimo'*, Livorno: Sillabe, 2014.
- Luca Ciancio, "Un interlocutore fiammingo di Fracastoro: il medico Iohannes Goropius Becanus (1518-1572) e la teoria dell'origine organica dei fossili," in Alessandro Pastore and Enrico Peruzzi (eds.), *Girolamo Fracastoro fra medicina, filosofia e scienze della natura*, Florence: Olschki, 2006, pp. 141-155.
- Carolus Clusius, *Rariorum aliquot stirpium per Hispanias Observatarum historia*, Antwerp: Plantin, 1576.
- Carolus Clusius, *Rariorum plantarum historia*, Antwerp: Plantin, 1601.
- Adriaen Coenen, *The Whale Book. Whales and other marine animals as described by Adriaen Coenen in 1585*, edited by Florike Egmond and Peter Mason, London: Reaktion Books, 2003.
- Harold Cook, *Matters of Exchange. Commerce, medicine, and science in the Dutch Golden Age*, Yale UP, New Haven & London, 2007.
- Sorana Corneanu, Guido Giglioni, Dana Jalobeanu, "The Place of Natural History in Francis Bacon's Philosophy," *Early Science and Medicine* 17 (2012), pp. 1-10.
- Peter Dear, "Towards a genealogy of modern science," in Lissa Roberts, Simon Schaffer, and Peter Dear (eds.), *The mindful hand. Inquiry and invention from the late Renaissance to early industrialisation*, Amsterdam: KNAW-EDITA, 2007, pp. 431-441.
- Pascal Duris, "L'introuvable révolution scientifique. Francesco Redi et la génération spontanée," *Annals of Science* 67 (2010), pp. 431-55.
- William Eamon and Françoise Paheau, "The accademia segreta of Girolamo Ruscelli. A sixteenth-century Italian scientific society," *Isis* 75 (1984), pp. 327-342.
- William Eamon, *Science and the secrets of nature. Books of secrets in medieval and early modern culture*, Princeton: Princeton University Press, 1994.
- Florike Egmond, *Het Visboek. De wereld volgens Adriaen Coenen*, Zutphen: Walburg Pers, 2005.

- Florike Egmond, *The World of Carolus Clusius: Natural History in the Making, 1550-1610*, London: Pickering & Chatto, 2010.
- Florike Egmond: "Observing nature. The correspondence network of Carolus Clusius," in Dirk van Miert (ed.), *Communicating Observations in Early Modern Letters, 1500-1575. Epistolography and Epistemology in the Age of the Scientific Revolution* [Warburg Institute Colloquia 23], London/Turin: Nino Aragno Editore (2013), pp. 43-72.
- Florike Egmond, *Eye for Detail. Images of Plants and Animals in Art and Science, 1500-1630*, London: Reaktion Books, 2017.
- Paula Findlen, "Controlling the experiment: rhetoric, court patronage and the experimental method of Francesco Redi," *History of Science* 31 (1993), pp. 35-64.
- Paula Findlen, *Possessing nature: museums, collecting and scientific culture in early modern Italy*, Berkeley: University of California Press, 1994.
- Paula Findlen, "Francis Bacon and the reform of natural history in the seventeenth-century," in Donald Kelley (ed.), *History and the Disciplines: the Reclassification of Knowledge in Early Modern Europe*, Rochester N.Y.: University of Rochester Press, 1997, pp. 239-260.
- Alette Fleischer, "Gardening Nature, Gardening Knowledge: The Parallel Activities of Stabilizing Knowledge and Gardens in the Early Modern Period," in H. Fischer et al. (eds.), *Gardens, Knowledge and the Sciences in the Early Modern Period*, Basel: Birkhäuser, 2016, pp. 289-304.
- Roger French, "Berengario da Carpi and the use of commentary in anatomical teaching," in Andrew Wear, R.K. French and I.M. Lonie (eds.), *The medical Renaissance of the sixteenth century*, Cambridge: Cambridge University Press, 1985, pp. 42-74.
- Stephen Gaukroger, *Descartes' System of Natural Philosophy*, Cambridge: Cambridge University Press, 2002.
- Piero Ginori Conti, *Lettere inedite di Charles de l'Escluse (Carolus Clusius) a Matteo Caccini, Floricoltore Fiorentino. Contributo alla storia della botanica*, Florence: Olschki, 1939.
- Anne Goldgar, *Tulipomania: Money, Honor, and Knowledge in the Dutch Golden Age*. Chicago: University of Chicago Press, 2007.
- Luigi Guerrini, *I Trattati Naturalistici di Federico Cesi*, Rome: Accademia dei Lincei, 2006.
- Deborah Harkness, *The Jewel House. Elizabethan London and the Scientific Revolution* New Haven and London: Yale University Press, 2007.
- Lynette Hunter, "Women and domestic medicine: lady experimenters, 1570-1620," in Lynette Hunter and Sarah Hutton (eds.), *Women, science and medicine: mothers and sisters of the Royal Society, 1500-1800*, Phoenix Mill: Sutton, 1997, pp. 89-107.
- Katrin Keller, "Kommunikationsraum altes Reich: Zur Funktionalität des Korrespondenznetze von Fürstinnen im 16. Jahrhundert," *Zeitschrift für Historische Forschung* 31 (2004), pp. 205-230.
- Ursula Klein, "The Laboratory challenge. Some revisions of the standard view of early modern experimentation," *Isis* 99 (2008), pp. 769-782.
- Jeanine de Landtsheer, "Justus Lipsius and Carolus Clusius, a flowering friendship,"

- Bulletin of the Belgian Institute* 68 (1998), pp. 273-295.
- G. E. R. Lloyd, "The Development of Aristotle's Theory of the Classification of Animals," *Phronesis* 6 (1961), pp. 59-81.
- Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600*, Cornwallis: Oregon State University Press, 2011.
- Maria Elena de Luca and Marzia Faietti (eds.), *Jacopo Ligozzi 'Altro Apelle'*, Florence: Giunti Editore, 2014, pp. 36-37.
- Bruce Moran, "Prince-practitioner and the Direction of Medical Roles at the German Court. Maurice of Hesse-Kassel and his physicians," in V. Nutton (ed.), *Medicine at the courts of Europe, 1500-1837*, London: Routledge, 1990, pp. 95-116.
- Antonio Neviani, "Ferrante Imperato. Speciale e naturalista Napolitano con documenti inediti," *Atti e memorie dell'Accademia di Storia dell'Arte Sanitaria* II, 2, (1936), pp. 57-74.
- Tara Nummedal, *Alchemy and authority in the Holy Roman Empire*, Chicago: Chicago University Press, 2007.
- Brian Ogilvie, *The Science of Describing. Natural History in Renaissance Europe*, Chicago: University of Chicago Press, 2006.
- Giuseppe Olmi, "La colonia Lincea di Napoli," in Lomonaco and Torrini (eds.), *Galileo a Napoli*, pp. 23-59.
- L. C. Palm (ed.), *Anthoni van Leeuwenhoek, Alle de brieven, Deel 11: 1695-1696*, Lisse: Swetz & Zeitlinger, 1983.
- Richard Palmer, "Medical Botany in Northern Italy in the Renaissance," *Journal of the Royal Society of Medicine* 78 (1985), pp. 149-157.
- S. Pumfrey, "The history of science and the Renaissance science of history," in S. Pumfrey, P. L. Rossi and M. Slawinski (eds.), *Science, Culture and Popular Belief in Renaissance Europe*, Manchester: Manchester University Press, 1991, pp. 48-70.
- S. Pumfrey and F. Dawbarn, "Science and patronage in England, 1570-1625. A preliminary study," *History of Science* 42 (2004), pp. 137-188.
- Alisha Rankin, "Becoming an expert practitioner. Court experimentalism and the medical skills of Anna of Saxony (1532-1585)," *Isis* 98 (2007), pp. 23-53.
- Marc Ratcliff, *The Quest for the Invisible. Microscopy in the Enlightenment*, Aldershot: Ashgate, 2009.
- Lissa Roberts, Simon Schaffer, and Peter Dear (eds.), *The mindful hand. Inquiry and invention from the late Renaissance to early industrialisation*, Amsterdam: KNAW-EDITA, 2007.
- Lesley Robertson et. al., *Antoni van Leeuwenhoek, Master of the Minuscule*, Leiden: Brill, 2016.
- Pamela Smith, *The Body of the Artisan. Art and Experience in the Scientific Revolution*, Chicago: Chicago University Press, 2004.
- Erica Stendardo, *Ferrante Imperato: collezionismo e studio della natura a Napoli tra Cinque e Seicento*, Naples: Accademia Pontaniana, 2001.
- Andrea Ubrizsy Savoia, "Il metodo sinottico, collante tra la *Syntaxis Plantarum* di Ulisse Aldrovandi e le *Tabulae Phytosophicae* di Federico Cesi," in Antonio Graniti (ed.), *Federico Cesi: Un principe naturalista*, Rome: Bardi Editore, 2006, pp. 525-555.

- M. Veneziani (ed.), *Experientia. X Colloquio Internazionale (Roma, 4-6 gennaio 2001). Atti*, Florence: Olschki, 2002.
- C. Webster, "The Recognition of Plant Sensitivity by English botanists in the seventeenth Century," *Isis* 57 (1966), pp. 5-23.

Manuscript letters

- Letters from J. de Boisot to C. Clusius (1582-1597), ULL, VUL 101.
- Letters from J. van Hoghelande to C. Clusius (1583-1593), ULL, VUL 101.
- Letter from J. Plateau to C. Clusius, 15 May 1596, ULL, VUL 101.
- Letters from F. Vertunien le Vau to C. Clusius (1599-1606), ULL, VUL 101.
- All original manuscript letters to and from Clusius in the collection of Leiden University can also be consulted online at <http://clusiuscorrespondence.huygens.knaw.nl/edition/>.

Manuscripts

- Adriaen Coenen, *Visboeck* (1577-81), c. 400 folios, Koninklijke Bibliotheek, The Hague, Ms 78 E 54.
- Adriaen Coenen, *Walvisboeck* (c. 1584-1585), Erfgoedbibliotheek Hendrik Conscience, Antwerp, Ms 392.
- Johannes and Theophilus Kentmann, *Codex Kentmannus*, Herzogin Anna Amalia Bibliothek, Weimar, Fol 323.