The Sciences of the Archive

by Lorraine Daston[*]

ABSTRACT

Since the mid-nineteenth century, classifications of knowledge have opposed the bookish, history-conscious humanities to the empirical, amnesiac sciences. Yet in the sciences of the archive, the library stands alongside the laboratory, the observatory, and the field as an important site of research. The sciences of the archive depend on data and specimens preserved by past observers and project the needs of future scientists in the creation of present collections. Starting in the early modern period, distinctive practices of weaving together the data of the archives and of present investigation have created a hybrid hermeneutics of reading and seeing.

PEOPLES OF THE BOOK

Since the mid-nineteenth century, it has been a melancholy academic commonplace that whereas the humanities are the guardians of memory, the sciences cultivate amnesia.[1] The story runs something like this. Humanists lovingly preserve their texts in libraries and reanimate them through the arts of exegesis, commentary, and interpretation; scientists, in contrast, ignore or (worse) discard any publication more than twenty years old, and the range of their citations rarely reaches back farther than five years. Scientists may pay homage to their great forebearers—the pantheon of Copernicus, Galileo, Newton, Darwin, Einstein—but they seldom read them and almost never cite them. In contrast, humanists are still in imagined dialogue with Plato and Dante, Shakespeare and Kant, Manu and Montaigne. Scientists notoriously take up the history of their field only in their dotage; if active scientists turn a stray thought to history, then it is usually to deride the errors of their predecessors. But the humanists seem to be engaged in a perpetual séance, raising the illustrious dead in their libraries.

This opposition of the bookish humanities, guardians of memory in the library, and the hands-on sciences, discoverers of timeless truths in the laboratory and the observatory, has its roots in mid-nineteenth-century classifications of the disciplines—first in bellwether German universities, with later echoes worldwide as other coun-

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[1] Thomas S. Kuhn drew a similar contrast between science and art (and mathematics): "For reasons and in ways that remain obscure to me, the sciences destroy their past more thoroughly than do mathematics or the arts." Kuhn, "The Halt and the Blind: Philosophy and History of Science," *Brit. J. Phil. Sci.* 31 (1980): 181–92, on 190 n. I thank Skuli Sigurdsson for drawing my attention to this passage.

tries instituted their own versions of the Humboldtian model of teaching united with research. In an influential speech delivered at the University of Heidelberg in 1862, for example, the physicist and physiologist Hermann von Helmholtz admitted that whereas the philologist and the historian, the jurist and the theologian considered the historical dimension essential to their disciplines, the scientist (*Naturforscher*) was "strikingly indifferent to literary treasures, perhaps even to the history of his own discipline." The humanist's memory must be richly provisioned with examples and cases in order to support the "artistic brand of induction" characteristic of these disciplines, but the regularity and generality of natural laws made the cultivation of this faculty largely otiose in the sciences.[2] On the side of the humanities, philosophers and historians of the stature of Wilhelm Windelband and Wilhelm Dilthey drove home the message that one of the essential distinctions between the *Geisteswissenschaften* and the *Naturwissenschaften* was the deeply historical sensibility of the former and the timeless perspective of the latter.[3]

Yet at about the same time that Helmholtz, Windelband, and Dilthey were drawing bold lines between the sciences of memory in libraries and the sciences of natural laws in laboratories and observatories, the most advanced scientific research institutions in Europe and North America were not only purchasing state-of-the-art instruments and building new temples to science; they were locating libraries at the heart of observatories and laboratories and busily stocking them. Here is the American astronomer Benjamin Gould rhapsodizing over the Russian Observatory at Pulkova, "the El dorado of astronomers," in 1849—the "magnificent" telescope with its Frauenhofer lens; the "exquisite execution" of the Repsold great meridian circle; and, directly opposite the main entrance, the library, replete with old as well as new books: "Of the library we will merely say, that no book of value on any department of astronomy is wanting which has been obtainable since the observatory was established, and that agents are employed all over Europe, ready to avail themselves of the first opportunity of acquiring rare books as they may happen to be in the market."[4] Or consider the Institute for Physiology at the University of Berlin (established 1882), which housed, in addition to dissection rooms, workshops, lecture halls, and lodgings for the staff, a library as large as one of the main laboratories (fig. 1). Or for that matter, the 1974 plans for the renovated Cavendish Laboratory at Cambridge University, which locate a library in the Bragg Building (fig. 2). All of these establishments were considered state-of-the-art when erected, powerhouses of the most advanced scientific research. And all of them contain libraries. Scientists too are people of books, and not just brand-new ones.

[2] Helmholtz, "Ueber das Verhältnis der Naturwissenschaften zur Gesammtheit der Wissenschaft" (Akademische Festrede gehalten zu Heidelberg beim Antritt des Prorektorats, 1862), in Helmholtz, *Vorträge und Reden*, 5th ed. (Braunschweig, 1903): 158–85, on 166, 171, 175–8.

[3] Windelband, "Geschichte und Naturwissenschaft" (Rektoratsrede, Universität Strassburg, 1894), in *Strassburg Universität: Gelegenheitsschriften, 1892–96* (Strasbourg, 1896): 15–41; Dilthey, "Der Aufbau der geschichtlichen Welt in den Geisteswissenschaften," in *Abhandlungen der Preußischen Akademie der Wissenschaften, Philosophisch-Historische Klasse* (Berlin, 1910): 1–123.

[4] Gould, "The Observatory at Pulkowa," *North American Review* 69 (1849): 143–62, on 143, 153, 155, 156. Among the rare books acquired by the Pulkova library were Johannes Hevelius's *Machina Coelestis* (1673) and unpublished manuscripts of Kepler, hardly the newest literature in the field circa 1850. See also Simon Werrett, "The Astronomical Capital of the World: Pulkova Observatory in the Russia of Tsar Nicholas," in *The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture*, ed. David Aubin, Charlotte Bigg, and H. Otto Sibum (Durham, N.C., 2010), 33–57.

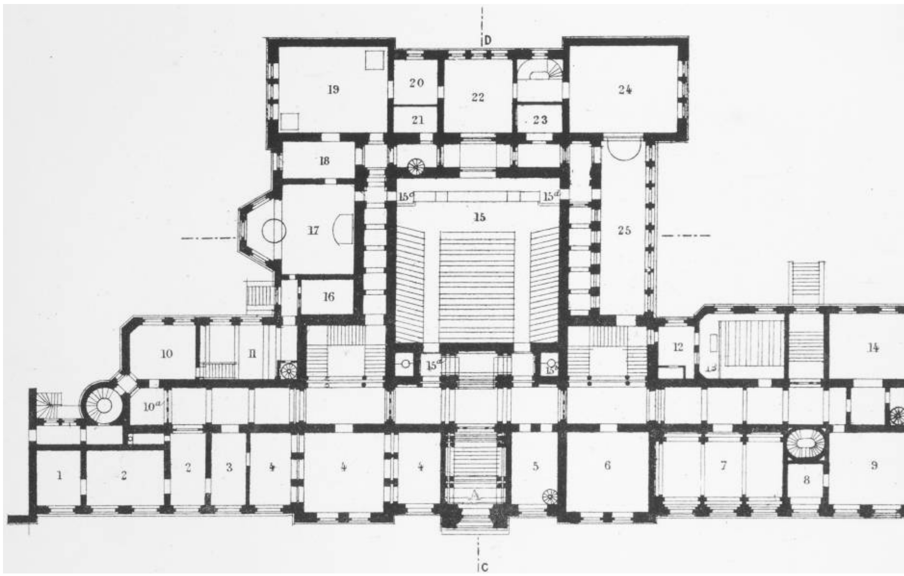


Figure 1. *Institut Physiologique de Berlin, plan du rez-de-chaussée. Nr. 7 is the library and reading room; nr. 17 is a physiological laboratory. Adolphe Wurtz,* Les hautes études pratiques dans les universités d'Allemagne et d'Autriche-Hongrie (Paris, 1882)*, vol. 2, planche IX. Reprinted by permission of the Max Planck Institute for the History of Science, Berlin.*

But what do they do with them? Books alone do not historians make. What is the historical consciousness of the sciences? It is hardly news to historians of science that the sciences have their own histories, and of several sorts. There are the intrinsically historical sciences, such as geology and evolutionary biology, which study natural processes fully as sensitive to context and contingency as any in human history across epochs and eons of billions of years.[5] There are the well-funded jubilees, most recently the Darwin Year, for which scientific societies solemnly gather to commemorate the life and works of some past titan.[6] There are the anecdotes, biographies, autobiographies, and lore that make up the long-lived mythology of scientific disciplines, praising heroes and blaming villains and more generally exemplifying core values like perseverance in adversity (as emblematized by Marie Curie stirring those vats of pitchblende) or studied disdain for social convention (as celebrated by almost all Einstein lore).[7] Yet these are not the genres that fill the shelves of working

[5] Martin J. S. Rudwick's *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago, 2005) provides the most comprehensive overview of how these sciences became historicized.

[6] On the history of such rituals of public commemoration and their spread from religious to secular occasions, see Winnfried Müller, ed., *Das historische Jubiläum: Genese, Ordnung und Inszenierungsgeschichte eines institutionellen Mechanismus* (Münster, 2004), and Paul Münch, ed., *Jubiläum, Jubiläum: Zur Geschichte öffentlicher und privater Erinnerung* (Essen, 2005). To my knowledge, there is no monograph devoted exclusively to the history of such anniversary commemorations in science (as opposed to eulogies and obituaries).

[7] This genre ultimately derives from Diogenes Laertius's *Lives of the Philosophers*; see Robert Goulet, *Études sur les vies des philosophes dans l'antiquité tardive* (Paris, 2001). For the history of

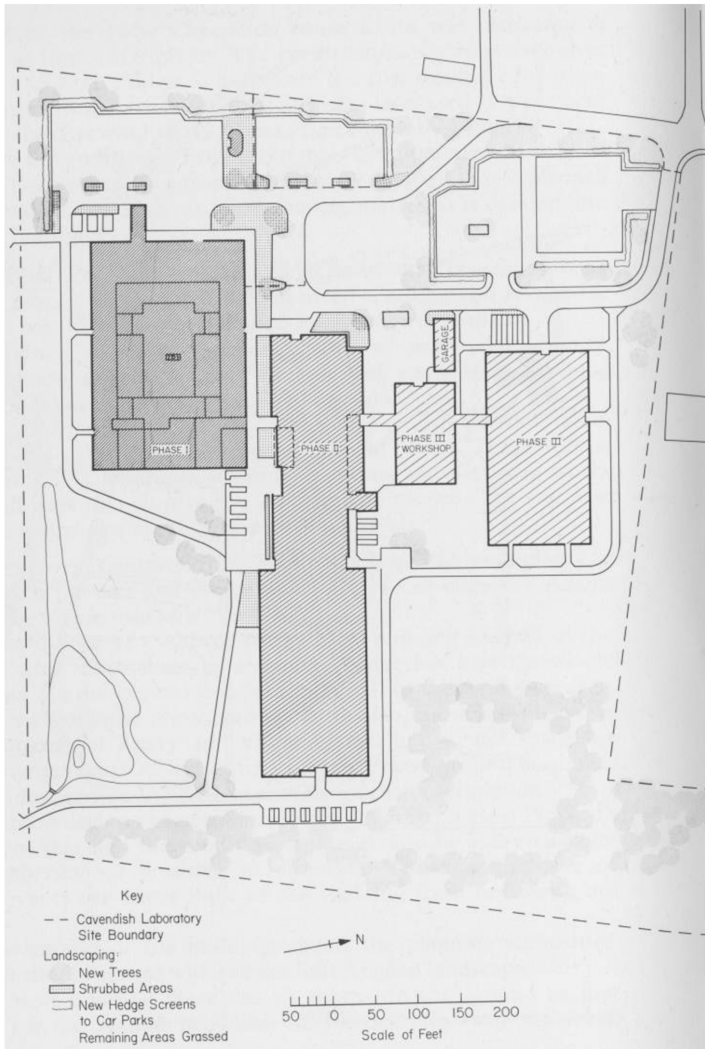


Figure 2. *Site plan of the New Cavendish. The Bragg Building (Phase II) is the middle structure. J. G. Crowther,* The Cavendish Laboratory, 1874–1974 *(New York, 1974), 424. Reprinted by permission of the University of Sussex Library.*

scientific libraries. There is another kind of historical consciousness—and historical practice—at work in at least some of the sciences. The way in which it works is the subject of this article: history *in* science.

By no means all sciences look to the past (or the future) with keen attentiveness. Moreover, the historicity of those that do is of different kinds. For some sciences,

science specifically, see Michael Shortland and Richard Yeo, eds., *Telling Lives in Science: Essays on Scientific Biography* (Cambridge, 1996), and Thomas Söderqvist, ed., *The History and Poetics of Scientific Biography* (Aldershot, 2007).

such as astronomy, geology, demography, and meteorology, the superhuman timescale of the phenomena under investigation and the extreme difficulty of discerning subtle correlations dictate the careful preservation and consultation of past observations, from ancient Babylonian star catalogs to medieval weather diaries to parish church records of births and deaths. Without the treasures stored up in libraries and archives, there would be no way to discern long-term trends in, say, climate or human mortality.

For other sciences, such as botany or zoology, the stability of the objects of inquiry depends crucially on a long disciplinary memory. The theoretical basis of the classifications of plants and animals has changed dramatically and repeatedly in the past three centuries, from morphology to phylogeny to cladistics to genetics. For just that reason, naturalists since the eighteenth century have attempted to standardize nomenclature and weld names of species permanently to the same objects (and since the early twentieth century, even to the same, unique "type specimens"[8]), no matter how a species may be defined.[9] The annotations made upon the herbarium sheet by past botanists who have studied a particular specimen are scrupulously preserved, along with the object itself (fig. 3); botanists conduct historical research to find out who collected which specimen where and whether the plant flattened on the herbarium sheet is identical with the one held in the hand of whoever made the initial classification. Linnaeus's herbarium, repository of many type specimens avant la lettre, is still a research tool in active use by botanical systematists.[10] Finally, almost any science can suddenly if briefly turn historical when confronted by a novel or anomalous phenomenon, which immediately prompts the question, Has this ever happened before, and if so, when, where, and how? History—more specifically, archiving data and specimens[11]—is integral to these sciences, which might collectively be called the sciences of the archive.

The historical consciousness of the sciences of the archive itself has a history. How long a history depends on the archiving practices of the various sciences: millennia for astronomy; only a few centuries for demography and botany. The intrinsically historical sciences, such as evolutionary biology and geology, do not necessarily qualify as sciences of the archives. Although fossils have been collected for centuries, and for the most diverse ends—to hang from church ceilings, to adorn *Wunderkammern*, to display nature's plastic powers, to study now-extinct species—it was only when they began to be collected and preserved systematically, with an eye toward future users,

[8] Lorraine Daston, "Type Specimens and Scientific Memory," *Crit. Inq.* 31 (2004): 153–82.

[9] Geoffrey C. Bowker, "The Game of the Name: Nomenclatural Instability in the History of Botanical Informatics," in *Proceedings of the 1998 Conference on the History and Heritage of Science Information Systems*, ed. Mary Ellen Bowden, Trudi Bellardo Hahn, and Robert V. Williams (Medford, N.J., 1999), 74–83. For the latest developments see Rebecca Ellis, "Rethinking the Value of Biological Specimens: Laboratories, Museums and the Barcoding of Life Initiative," *Museum and Society* 6 (2008): 172–91.

[10] Charlie Jarvis, "A Concise History of the Linnean Society's Linnaean Herbarium, with Some Notes on the Dating of the Specimens It Contains," in "The Linnaean Collections," special issue no. 7, ed. B. Gardiner and M. Morris, *Linnean* 23 (2007): 5–18. The Linnaean Herbarium, already preserved in a strong room in London, is now being digitized, a further step in archiving its contents, as described on the website of the Linnean Society, http://www.linnean.org/index.php?id=326 (accessed 30 August 2011).

[11] Although the focus of this article will be the storage and retrieval of data, the practices of collecting objects in the geo- and biosciences constitute an important parallel; see Bruno Strasser, "Laboratories, Museums, and the Comparative Perspective: Alan A. Boyden's Seriological Taxonomy, 1925–1962," *Hist. Stud. Nat. Sci.* 40 (2010): 149–82, and Strasser's article in this volume.

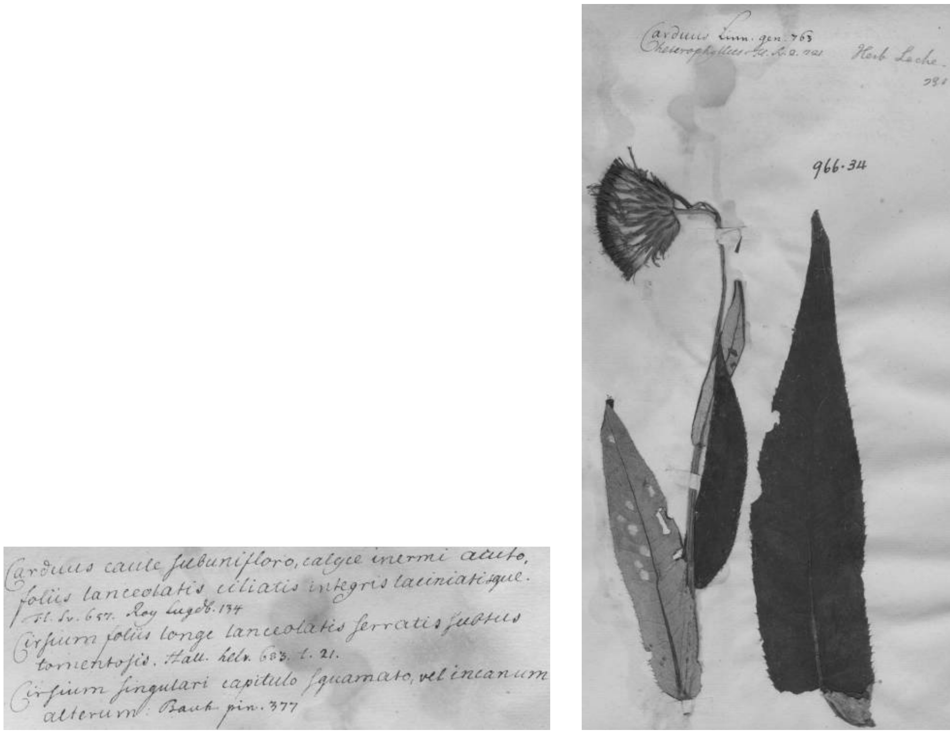


Figure 3. Carduus sp. *(LINN 966.34). Digitalized specimen from Linnaeus's herbarium, including not only the plant itself but also annotations by Johan Leche, a professor of medicine and botanist who sent Linnaeus observations and plant specimens. The Linnean Society of London Collections Online, http://www.linnean-online.org/9833/ (accessed 1 September 2011). Copyright Linnean Society of London. Reprinted by permission of the Linnean Society of London.*

that paleontology became a science of the archives. The idea of taking and storing core samples from various locations on the Earth as a reference collection for future geologists is another (and still more recent) archival practice.[12] It is not just a deep time dimension in the phenomena investigated that is the hallmark of the sciences of the archives, but rather the practice of storing up materials for future investigators. One historical precondition for such archival practices is the sense of a community of inquirers—not necessarily a discipline, much less an institutionalized one—that extends into the future as well as the past. And this sense in turn often goes hand-in-hand with an awareness of the enormity of the investigative task, which demands a legion of inquirers to do it justice.

Like all stereotypes, the one of humanists worshiping their ancestors, faces turned reverently toward the past, and scientists committing disciplinary patricide, gaze riveted on the future, contains elements of truth. And like all stereotypes, it distorts and occludes. It freeze-frames a nineteenth-century contrast of disciplines steeped in history versus those oblivious or even hostile toward it, of the curators of the library and

[12] National Research Council, *Geoscience Data and Collections: National Resources in Peril* (Washington, D.C., 2002).

the museum versus those of the laboratory and the observatory. My aim here is to undermine these habitual oppositions—and in so doing, to challenge reigning classifications of knowledge that still mold the ways in which the histories of science and scholarship are written.

COLLECTIVE EMPIRICISM: ENDLESS DATA, INFINITE LABOR

Pace the stereotypes, the library has never ceased to be a site of scientific knowledge, alongside the laboratory and the observatory—often literally alongside, as architectural plans of research institutions from the seventeenth century to the present reveal.[13] Its enduring and indispensable presence at the heart of scientific endeavor bears witness to the deep historicity of certain sciences. The library in these sciences is literal, not metaphorical. It is a repository of not only books but also manuscripts, registers, notebooks, and correspondence—an archive. It is the product of human labor, not natural processes (in contrast to, e.g., fossils metaphorically understood as a "record" of past life forms: "the many volumes of botany representing in the same quarry the oldest library in the world," as the eighteenth-century French naturalist Antoine de Jussieu described his discovery of plant imprints in the stones of the Lyonnais[14]). What distinguishes the sciences of the archive from other sciences is not just a historical dimension of the phenomena they study nor even the practice of taking, making, and keeping data. Rather, it is practices of collection, collation, and preservation conceived as an intrinsically collective undertaking—and one that extends into both past and future. The sciences of the archive are either too grand in scale or simply too much work for an individual or even a generation.

The history of collective empiricism in the sciences varies by discipline: astronomy pioneered its practices in the ancient world; medicine organized itself into an exchange network in the early modern period; chemistry was a relative latecomer. René Descartes was perhaps the last major figure to fantasize about science conducted in splendid solitude, alone in a bare study without books, in search of "truths that can be deduced from things known and ordinary," as opposed to the sort of knowledge that "required, first of all, to have researched all the plants and stones that come from the Indies, to have seen the phoenix, and in short to overlook nothing of all that is strangest in nature."[15] But even Descartes recanted in his *Discours de la*

[13] Anthony Grafton has described the importance of libraries for early modern science, but there are very few studies about their role thereafter (in contrast to the large literature on scientific museums or on the history of libraries more generally); Grafton, "Libraries and Lecture Halls," in *Early Modern Science*, ed. Katharine Park and Lorraine Daston, vol. 3 of *The Cambridge History of Science* (New York, 2006), 238–50. A notable exception is the excellent introductory essay on the eighteenth-century scientific library in Marco Beretta, *Bibliotheca Lavoisieriana: The Catalogue of the Library of Antoine Laurent Lavoisier* (Florence, 1995), 13–58. Geoffrey C. Bowker's *Memory Practices in the Sciences* (Cambridge, Mass., 2005) is an essential introduction to metaphors and practices in selected modern sciences and highly suggestive concerning the ways in which scientists imagine data and the past.

[14] Jussieu, "Examen des causes des impressions des plantes marquées sur certaines pierres des environs de Saint-Chaumont dans le Lionnais," *Mémoires de l'Académie Royale des Sciences* (Paris, 1718), 287–97, on 289.

[15] Descartes, "La recherche de la verité par la lumière naturelle" (comp. 1628/9?; pub. in Dutch 1684, Latin 1701), in *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery (Paris, 1966), 10:459–532, on 503. The dating of this unfinished manuscript is uncertain, but the most recent critical edition argues for a date before 1637; Ettore Lojanco with Erik Jan Bos, Franco A. Meschini, and Francesco Saita, eds., *"La recherche de la verité par la lumière naturelle" de René Descartes* (Milan, 2002).

méthode (1637), admitting that his grand project for a new natural philosophy would require "many experiments," and explained that one of his principal motivations in publishing his preliminary discoveries was "to urge men of ability to continue the work by contributing, each one according to his inclinations and abilities, to the experiments that must be made."[16] In a private letter to King James I accompanying the presentation copy of the *Novum Organum* (1620), Francis Bacon similarly hoped that even premature publication would attract recruits to "help in one intended part of this work, namely, the compiling of a natural and experimental history, which must be the main foundation of a true and active philosophy."[17] Bacon failed to win royal support, and his own ambitious project for 130 natural histories of everything from comets to sleep and dreams faltered for lack of time, money, and manpower.[18]

Nothing daunted, the fledgling northern European scientific academies founded in the mid-seventeenth century reiterated calls for volunteers far and wide to submit observations and experiments to be published in their journals: the *Miscellanea Curiosa* of the Academia Naturae Curiosorum (est. 1652, later known as the Leopoldina), the *Philosophical Transactions* of the Royal Society of London (est. 1660), and *Histoire et mémoires de l'Académie Royale des Sciences* in Paris (est. 1666). The challenge of recruiting, training, and coordinating an army of observers and experimenters, both paid and volunteer, has preoccupied the sciences ever since, as research-grant proposals from Bacon's requests to James I to the Internet *levée en masse* for the Encyclopedia of Life project bear witness.[19] Because nature is vast and labyrinthine, empiricism in the natural sciences is hugely labor intensive—and therefore collective.[20]

Of necessity collective empiricism spans continents and generations. The phenomena to be investigated are myriad and global (if not cosmic); merely to catalog them all would be the work of centuries (if not millennia). Whatever the rhetoric of firsthand observation (*sola autopsia* echoing the Protestant *sola scriptura* since the sixteenth century), the reality is that the modern empirical sciences have always and essentially depended on testimony.[21] Like historians, scientists must gather, weigh, and amalgamate the testimony of witnesses who are more or less sagacious, more or less thorough, more or less trustworthy. Depending on whether the dimension of space or time dominates in the collective empiricism practiced by a particular science, the witnesses may be contemporaries in other places or observers from other epochs. Because the bulk of scientific testimony has accumulated over decades and

[16] Descartes, "Discours de la méthode" (1637), in Adam and Tannery, *Oeuvres de Descartes* (cit. n. 15), 4:130–47. On the interplay of deduction and experiment in Descartes's natural philosophy, see Daniel Garber, *Descartes Embodied: Reading Cartesian Philosophy through Cartesian Science* (Cambridge, 2001), 85–110.

[17] Bacon to James I, 12 October 1620, quoted in Lisa Jardine and Alan Stewart, *Hostage to Fortune: The Troubled Life of Francis Bacon* (New York, 1998), on 438. Bacon reiterated his request more pointedly to James himself: "This comfortable beginning makes me hope further, that your Majesty will be aiding me in setting men to work for the collecting of a natural and experimental history; which is the *basis totius negotii*" (439). See also Bacon, "Epistola Dedicatoria," in *Novum Organum*, vol. 9 of *The Works of Francis Bacon*, ed. Basil Montagu (London, 1828), on 150.

[18] See the "Catalogus Historiarum Particularum" appended to the "Parasceve ad Historiam Naturalem, et Experimentalem," in Montagu, *Works of Francis Bacon* (cit. n. 17), 11:427–36.

[19] See "Help Build EOL" on the Encyclopedia of Life website, http://www.eol.org/content/page/help_build_eol (accessed 29 August 2010).

[20] Lorraine Daston and Peter Galison, *Objectivity* (New York, 2007), 19–27, 367–8.

[21] Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago, 1994); see also Martin Kusch and Peter Lipton, "Testimony: A Primer," *Stud. Hist. Phil. Sci.* 33 (2002): 209–17.

often centuries, collective empiricism must always be in part historical, albeit to different degrees: the data reside in the library as well as in the laboratory and the observatory. There is nothing new about data mining per se.

The word *data* is, however, a slippery one; "the givens" (originally, those things that are given in a Euclidean geometric proof or construction) are indeed given, but by whom, and to what end? Historians have evolved a princess-and-the-pea sensibility concerning what their own archives give them: what was selected for preservation (and what not) and why; how data were organized both physically and conceptually; who had access to them; what purposes they were meant to serve.[22] Scientists also cross-examine their current data: the circumstances under which they were collected; the instruments used; the reliability of the reporter; the possible sources and size of error; the robustness of the phenomenon. Do they also query past data? To do so is immediately to plunge into the same quandaries that confront historians and to run the same risks of anachronism. For example, both the social historian and the historical demographer must probe the local circumstances under which parish records were kept and determine where systematic and strategic omissions are likely.[23] To use past data is willy-nilly to become a historian.

Unlike historians, however, scientists occasionally construe their own present data as the past data for future scientists: they become archivists. They self-consciously create the archives for an imagined community of disciplinary descendants, just as they embrace past observers in an imagined disciplinary lineage.[24] Just how far this sense of a community of data inherited and passed on stretches is variable, according to the timescale of the science. In astronomy, for example, it has extended across millennia in both directions, from ancient Mesopotamian star watchers in 1200 BCE to the astronomers of the year 3000 CE. This Janus-faced perspective of the scientific archive, reaching back into the past and forward into the future, sets it apart from the traditional historical archive.[25]

How does this vision of a century-spanning imagined community inform the creation and use of scientific archives of data? What are the ways in which present and past data, first- and secondhand experience, come to be spliced together? If the experiment is the reigning practice of the laboratory and the observation that of the

[22] For the history of science specifically, see Michael Hunter, ed., *Archives of the Scientific Revolution: The Formation and Exchange of Ideas in Seventeenth-Century Europe* (Woodbridge, 1998), and Ann Blair and Jennifer Mulligan, eds., "Toward a Cultural History of the Archives," special issue, *Archival Science* 7, no. 4 (2007).

[23] E.g., in the case of the frequency of infanticide; for discussions of the impact of shifting definitions and sanctions on records, see Richard van Dülmen, *Frauen vor Gericht: Kindermord in der frühen Neuzeit* (Frankfurt, 1991); Adriano Prosperi, *Die Gabe der Seele: Geschichte eines Kindermordes*, trans. from Italian by Joachim Schulte (Frankfurt, 2007); Keith Wrightson, "Infanticide in European History," *Criminal Justice History* 3 (1982): 1–20.

[24] I borrow the evocative phrase "imagined community" from Benedict Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism* (London, 1983). Anderson's prime example is the modern nation, but the term might be applied with equal justice to the republic of letters or the scientific community, both of which embrace members who may never meet face-to-face and who may even remain anonymous to one another. The imaginary dimension is if anything even more pronounced in these conjured confraternities of the learned, since they lack even the territorial concreteness of the nation.

[25] This may be changing, though, as archivists overwhelmed by the sheer volume of materials try to divine what future historians will be interested in so as to develop criteria for what should and should not be preserved—or simply abandon the process to random sampling; K. J. Smith, "Sampling and Selection: Current Policies," in *The Records of the Nation: The Public Record Office, 1838–1988; the British Record Society, 1888–1988*, ed. G. H. Martin and Peter Spufford (Woodbridge, 1990), 49–59.

observatory, what goes on in the scientific library? The answers to these questions deserve volumes. What I offer here are some examples, drawn from several disciplines and time periods, that suggest the richness of the topic—and the magnitude of its implications for how we understand science and its histories. The next section describes how early modern genres of empirical scientific inquiry, such as *historiae* and *observationes*, tended to blur the boundary between words and things by applying similar practices to book learning and the study of nature. I then examine in detail how reading and observing practices merged in early modern natural history, creating a hybrid hermeneutics of first- and secondhand experience. The article concludes with some reflections on the conceptions of history and imagined community that govern the taking, making, and keeping of data in the scientific archive.

GRANARIES AND TREASURIES OF KNOWLEDGE

The seventeenth-century *Kunstkammer* of the Regensburg iron-dealer family Dimpel exhibits the usual profusion of *naturalia* and *artificialia*: cannons (paying homage to the family business), exotic shells, globes and instruments, Chinese porcelain, paintings—and books, stacked on the table and arrayed on the shelf (fig. 4). The combination of books with other collectibles in the same space was not exceptional in the early modern period,[26] even in the large princely libraries that later became the core of nineteenth-century national libraries. Sometimes the proximity of books and specimens was even closer, alarmingly so: the Paris Académie Royale des Sciences, housed in the Bibliothèque du Roi until 1699, conducted dissections and vivisections in the library, "fitting a table with straps to restrain live subjects."[27]

The promiscuous mixture of words and things in these early modern sites of science is almost as disconcerting to modern eyes as the studied miscellany of art and nature in the Wunderkammern. Nor would the incongruity be much softened by paying attention to early modern pronouncements on the immiscibility of book learning and the reformed study of nature. Many sixteenth- and seventeenth-century manifestos polemically opposed the knowledge of words to that of things: from Paracelsus's railings against learned doctors to Royal Society apologetics, from Francis Bacon's critique of the Idols of the Marketplace to Gottfried Wilhelm Leibniz's fascination with Chinese pictograms as thing-like words—the acute sense of a chasm yawning between words and the things they purportedly represented was ubiquitous. On the side of words, schemes for artificial languages, like those of Amos Comenius or John Wilkins, and on the side of things, new forms of disciplined experience, such as collecting and experimenting, were devised to bridge this gap. Yet what was explicitly conceived as a challenge of representation—how best to mirror the world of things faithfully in both word and image—was implicitly also one of practice: how were bookish scholars trained to handle, appraise, and coin words to learn to manipulate, assay, and order things?

As the architectural juxtaposition of books, natural history collections, and even

[26] For other examples, see Beretta, *Bibliotheca Lavoisieriana* (cit. n. 13), 20–7. For a sense of the early modern connections between research in books and on things, see Anthony Grafton, "Where Was Salomon's House? Ecclesiastical History and the Intellectual Origins of Bacon's *New Atlantis*," in *Worlds Made by Words* (Cambridge, Mass., 2009), 98–113.

[27] Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences* (Berkeley and Los Angeles, 1990), 39.

Figure 4. *Joseph Arnold,* Cabinet of Art and Rarities of the Regensburg Iron Dealer and Mining Family Dimpel *(1668). Copyright Ulmer Museum, Ulm, Germany; photo: Oleg Kuchar, Ulm. Reprinted by permission of the Ulmer Museum.*

dissecting rooms and chemical laboratories suggests, the reformed natural philosophers of the early modern period retooled reading into observing. Thanks to the work of Ann Blair, Anthony Grafton, Gianna Pomata, Nancy Siraisi, Brian Ogilvie, Adrian Johns, and other historians of early modern science and scholarship, we know a great deal about how Renaissance humanist techniques like the making of compendia and the keeping of commonplace books merged with the collection of observationes, the assembling of historiae, and an eagle eye for minute differences—whether in collating manuscripts of Cicero or classifying plant species.[28] Two examples, both central

[28] There is a large literature on early modern reading practices, but still seminal is Roger Chartier, *Lectures et lecteurs dans la France d'ancien régime* (Paris, 1987). On learned reading, see Guglielmo Cavallo and Chartier, eds., *A History of Reading in the West* (1997), trans. Lydia G. Cochrane (Cambridge, 1999), especially the essays by Jacqueline Hamesse, "The Scholastic Mode of Reading," 103–19, and Grafton, "The Humanist as Reader," 179–212; Bernhard Fabian, "Der Gelehrte als Leser," in *Buch und Leser*, ed. Herbert G. Göpfert, Wolfenbüttler Arbeitskreis für Geschichte des Buchwesens (Hamburg, 1977), 48–88; Blair, "Humanist Methods in Natural Philosophy: The Commonplace Book," *J. Hist. Ideas* 53 (1992): 541–51; Blair, *The Theater of Nature: Jean Bodin and Renaissance Science* (Princeton, N.J., 1997); Johns, "Reading and Experiment in the Early Royal Society," in *Reading, Society and Politics in Early Modern England*, ed. Kevin Sharpe and Steven Zwicker (Cambridge, 2003), 244–71; Blair, "Note-Taking as an Art of Transmission," *Crit. Inq.* 31 (2004): 85–107; Blair, "Scientific Reading: An Early Modernist's Perspective," *Isis* 95 (2004): 64–74; Blair, *Too Much to Know: Managing Scholarly Information before the Modern Age* (New Haven, Conn., 2010). On the use of such techniques in the compilation of observationes, see Pomata, "Observation Rising: Birth

to early modern learned empiricism, show how fluid the boundary between the study of books in a library and the study of the book of nature could be during this period: the compilation of a historia and the making of an observatio.

The historia, from the Greek work for enquiry, was traditionally opposed and subordinated to *philosophia* (or poetry) following Aristotle's contrast of the two genres in the *Poetic*s: "Hence poetry is something more philosophic and of graver import than history, since its statements are rather of the nature of universals, whereas those of history are singulars."[29] Historia in the ancient, medieval, and early modern sense did not necessarily involve a temporal dimension (a usage still fossilized in the term *natural history*). As Aristotle's derogatory comparison indicates, the defining characteristic of historia was that it dealt in particulars—and was therefore at best a means to the end of universal generalizations. In the course of the sixteenth century, however, the epistemic prestige of both civil and natural history was on the rise, and the sturdy particulars of historia were increasingly regarded as more reliable than the airy universals of philosophia.[30] By the early seventeenth century, natural history seemed to some the foundation upon which natural philosophy must be rebuilt. In his programmatic *Distributio Operis* (1620), Bacon saw "no hope therefore of greater advancement and progress unless by some restoration of the sciences. But this must commence entirely with natural history."[31] The historia was now understood to be an omnium-gatherum of all that was known on a subject, following the example of Pliny's encyclopedic *Historia naturalis*, which boasted in its preface that it included 20,000 items:[32] the winds, life and death, quicksilver, smell and odors. Bacon's ambitious "Catalogue of Particular Histories" was to be executed by "the joint application of others," but he began several model histories on his own, including the unfinished *Sylva Sylvarum*, in order to recruit and guide collaborators.[33] He was probably drawing upon models of historiae compiled in the sixteenth century, mostly by doctors, who had already recognized that only a collective could accomplish such works.[34]

These collectives were largely virtual in nature, composed of correspondents and,

of an Epistemic Genre, 1500–1650," in *Histories of Scientific Observation*, ed. Lorraine Daston and Elizabeth Lunbeck (Chicago, 2011), 45–80; and on the overlap between Renaissance philological and botanical practices, see Ogilvie, *The Science of Describing: Natural History in Renaissance Europe* (Chicago, 2006).

[29] Aristotle, *Poetics*, 1451b5–7, in *The Complete Works of Aristotle*, 2 vols., ed. Jonathan Barnes (Princeton, N.J., 1984), 2:232. Still seminal for understanding the convoluted meanings of historia in early modern Europe is Arno Seifert's *Cognitio Historica: Die Geschichte als Namengeberin der frühneuzeitlichen Empirie* (Berlin, 1976); for the sense of historia discussed in this article, see esp. 116–49.

[30] Paula Findlen, "Natural History," in Park and Daston, *Early Modern Science* (cit. n. 13), 435–68; Gianna Pomata and Nancy G. Siraisi, eds., "Introduction" and "The Ascending Fortunes of Historia," in *Historia: Empiricism and Erudition in Early Modern Europe* (Cambridge, Mass., 2005), 1–40.

[31] Bacon, "The Distribution of the Work," in Montagu, *Works of Francis Bacon* (cit. n. 17), 14:14–24, on 20.

[32] Pliny the Elder, "Preface," in *Natural History*, 10 vols., trans. H. Rackham, Loeb Classical Library (Cambridge, Mass., 1989), 17. On the many early modern editions and reception of Pliny, see Charles G. Nauert Jr., "Humanists, Scientists, and Pliny: Changing Approaches to a Classical Author," *Amer. Hist. Rev.* 84 (1979): 72–85.

[33] Bacon, "A Preparation for a Natural and Experimental History" (1620), in Montagu, *Works of Francis Bacon* (cit. n. 17), 14:213–6, on 215. Of the 130 historiae listed in Bacon's catalog, over thirty were on medical topics.

[34] Gianna Pomata, "*Praxis Historialis*: The Uses of Historia in Early Modern Medicine," in Pomata and Siraisi, *Historia* (cit. n. 30), 105–46.

above all, authors of books, both ancient and modern. Despite a great deal of speechifying about the superiority of firsthand over secondhand experience and the dangers of bowing to ancient authorities, the lion's share of the work of putting together a historia, that bulwark of early modern empiricism, was done in a well-stocked library. Against the background of a rhetoric that trumpeted the virtues of things over words, experience over erudition, this is perhaps shocking, but it should not be surprising. The ambitions of early modern historia, which aimed to embrace all the phenomena of the universe, could hardly be realized by a single investigator or even by a legion of them, no matter how long and diligently they labored. Nothing less than the collective experience of all of humanity would be adequate to the task. And the repository of that *longue durée* experience was the library, not the observatory, the laboratory, or even the museum.

Take the case of Bacon's own historia, the *Sylva Sylvarum*. Of the thousand items (ten "centuries" of one hundred items each) assembled therein, at least a third were taken from other sources, ranging from Aristotle and Pliny to Giambattista della Porta and Girolamo Cardano—a proportion so large that a modern editor of Bacon's manuscripts felt obliged to defend him against charges of plagiarism.[35] Bacon's surviving manuscript notes for the project demonstrate how particulars derived from books and from experiment were literally interleaved: the marginalia that annotate the "experiments" to be performed sometimes reference a source (e.g., "Aristotle"), sometimes are reported as testimony ("It was reported by a sober Man, that an Artificial Spring may be made thus"), and sometimes as personal observation ("Done Octob. 10 put a green Apple into Hay, and leave another of the same Apple to compare with it, and see how much sooner the one will sweeten and ripen than the other").[36] Such intermingling of reading notes and hearsay with experiments and observations does not imply that Bacon was indiscriminate or a traitor to his own empiricist principles; rather, it suggests that reading and observing were activities almost always pursued in tandem—and together with others, both the quick and the dead.[37]

Other examples of seventeenth-century historiae bear out this claim. The Academia Naturae Curiosorum, established in Schweinfurt in 1652 as an academy of learned doctors (mostly municipal physicians practicing in the Holy Roman Empire), resolved in its early statutes that each member would earn his stripes (signified by a ring and a special nickname) and further the advance of knowledge by writing a historia on the medicinal properties of some natural substance: "To be researched is the name of the substance under investigation, the synonyms, the development, place of origin, the differences, the species, the selection, the effects of the whole as well as its parts, the usual and chemical medications that can be prepared from it, both simple and mixed. . . . To this end, he [the author] will draw upon recognized authors,

[35] Graham Rees, "An Unpublished Manuscript of Francis Bacon: *Sylva Sylvarum* Drafts and Other Working Notes," *Ann. Sci.* 38 (1981): 377–412, on 388–9.

[36] [Francis Bacon/William Rawley], British Library St. Pancras Additional MSS 38, 693, fols. 31r, 32r, 43v. On the provenance and identification of the manuscript, see Rees, "Unpublished Manuscript" (cit. n. 35), 378–81. See also Richard Yeo, "Between Memory and Paperbooks: Baconianism and Natural History in Seventeenth-Century England," *Hist. Sci.* 45 (2007): 1–46.

[37] On the influence on the early Royal Society of Bacon's "granary" model of archiving scientific observations, see Mordechai Feingold, "Of Records and Grandeur: The Archive of the Royal Society," in Hunter, *Archives of the Scientific Revolution* (cit. n. 22), 171–84.

his own observations, and credible reports and perceptions of others."[38] A few works were completed and published along these lines, offering copious erudition and experience intermingled.[39] The prerequisites for fulfilling this requirement were leisure and a substantial personal library, like that of the first president, Johannes Laurentius Bausch.[40] Neither was readily available to the intended membership of *Stadtphysici*; fourteen of the twenty-three candidates initially invited to join declined.[41]

The expedient adopted by the Academia Naturae Curiosorum to overcome these impediments to recruitment might at first seem a decisive shift from bibliographic to empirical research. Instead of composing a weighty historia, physicians and other learned persons might instead send in short observationes on medical and natural historical topics, which would then be collected and published in the Academia's journal *Ephemerides* (sometimes titled *Miscellanea Curiosa*), with full credit given to the correspondents who submitted the observations. The call was issued to Europe at large, promising that correspondents would be treated "in a courteous, honorable, and friendly manner" and that they would enjoy fame and the gratitude of mankind without having to take the time and trouble to write a big book.[42] As academician Philipp Jakob Sachs von Lewenhaimb explained in his letters to Chemnitz town physician Christian Friedrich Garmann, even those devotees of things "physico-medical" not in the possession of "medical libraries" could participate.[43]

Yet although many of the short, numbered observationes were firsthand reports by named contributors, they were interspersed with items excerpted from other accounts: for example, "Observatio XXXIX," sent in by a Dr. Joachim Elsner, quotes an Italian account of male and female conjoint twins, modestly separated by a placenta, along with a Latin commentary that the cohabitation of brother and sister is contrary to natural law (in the legal sense: *jus naturae*, not *lex naturalis*) (fig. 5).[44] Throughout the volume are strewn scholia relating this or that isolated observation to similar phenomena reported in ancient and modern sources.[45] Whatever the

[38] [Academia Naturae Curiosorum], *Leges* (III, IV) [1652], quoted in Uwe Müller, "Die Leopoldina unter den Präsidenten Bausch, Fehr und Volckamer, 1652–1693," in *350 Jahre Leopoldina: Anspruch und Wirklichkeit*, ed. Benno Parthier and Dietrich von Engelhardt (Halle, 2002), 45–93, on 50. The complete text of the 1662 statutes is reproduced in Andreas Büchner, *Academiae Sacri Romani Imperii Leopoldino-Carolinae Naturae Curiosorum Historia* (Halle/Magdeburg, 1755), 187–97.

[39] E.g., Philipp Jacob Sachs von Lewenhaimb's *ΑΜΠΕΛΟΓΡΑΦΙΑ, sive Vitis Viniferae* (Leipzig, 1661), which runs to 671 pages and includes a "catalogus authorum" of works cited.

[40] On Bausch's large library of some six hundred books, see Uwe Müller, Claudia Michael, Michael Bucher, and Ute Grad, *Die Bausch-Bibliothek in Schweinfurt*, Acta Historica Leopoldina 32 (Halle, 2004).

[41] Wieland Berg, "Die frühen Schriften der Leopoldina—Spiegel zeitgenössischer Medizin," *NTM—Schriftenreihe Geschichte der Naturwissenschaften, Technik, Medizin* 22 (1985): 67–76, on 69.

[42] "Epistola Invitatoria ad Celeberrimos Medicos Europae," *Miscellanea Curiosa Medico-Physica Academiae Naturae Curiosorum* 1 (1670): n.p. The observationes (160 in toto) are prefaced with a "syllabus" listing the names of the thirty-six contributors (only ten of whom were members of the Academia Naturae Curiosorum).

[43] Sachs von Lewenhaimb to Garmann, 4 July 1670, quoted in Müller, "Die Leopoldina" (cit. n. 38), on 62. The correspondence makes clear that Sachs von Lewenhaimb modeled the *Ephemerides* on the *Philosophical Transactions* of the Royal Society of London and the French *Journal des savants*.

[44] Joach[im] Georg Elsner, "Observatio XXXIX," *Miscellanea Curiosa* 1 (1670): 119–27. The Italian report is quoted on 127: "La sagicissima Natura in una particular membrana separata dal Maschio conserva la femmina."

[45] Most but not all of the observationes are followed by a scholion that relates them to other observations and texts and sometimes attempts an explanation of the reported phenomenon. The learned scholion was already a fixture of the medical *curationes* and observationes literature by the latter

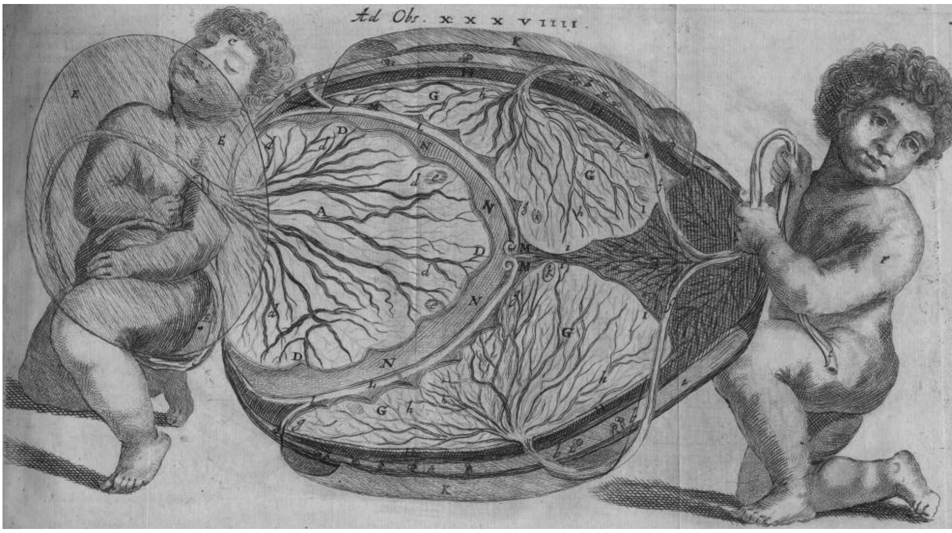


Figure 5. *Male and female twins modestly holding a placenta between them. Elsner, "Observatio XXXIX" (cit. n. 44), 127. Reprinted by permission of the Max Planck Institute for the History of Science, Berlin.*

bibliographic resources of the contributors, the editors saw it as their role to knit the firsthand observations submitted to them into a web of literature stretching from the latest number of the *Philosophical Transactions* all the way back to Galen and Hippocrates.[46]

And for the most Hippocratic of reasons: ars longa, vita brevis. As Bausch explained in the founding document of the Academia Naturae Curiosorum, the works of God in the vegetable, mineral, and animal realms were "innumerable, and to such an extent, that the lifetime of a single person does not suffice to investigate and know them precisely no matter how ardent the desire for knowledge; [but] this failing, which lies in the fact that the lifespan of an individual is too short to do justice to the innumerable natural phenomena to be researched, can perhaps be compensated for by several people banding together to work with shared dedication."[47] For so enormous a task no academy—not even the entire republic of letters—was adequate. Observations and experiments, especially of rare phenomena like comets or monstrous births, were too precious to ignore, however long ago and far away and therefore suspect their origins might be. Early modern compendia of these valuable items were often referred to as *thesauri*, "treasuries."[48] This was a fortiori the case for astronomical observations, which were difficult and expensive to make, and often tracked pe-

half of the sixteenth century; see Pomata, "Observation Rising" (cit. n. 28), 56. The early *Histoires* published by the Paris Académie Royale des Sciences served much the same contextualizing purpose for the *Mémoires*.

[46] There are obvious parallels between these compilation techniques and those used by humanists composing florilegia, commonplace books, and other collections of texts (complete with complaints about the endless labor involved); Blair, *Too Much to Know* (cit. n. 28), 173–229.

[47] Johann Laurentius Bausch, "Epistola Invitatoria" (1652), quoted in Müller, "Die Leopoldina" (cit. n. 38), 49–50.

[48] Pomata, "Observation Rising," on 56; see also Blair, *Too Much to Know*, on 113–6 (Both cit. n. 28).

riodic phenomena with cycles that were decades, centuries, or even millennia long. When, for example, Parisian astronomer and academician Gian Domenico Cassini I observed a strange light in the constellations of the zodiac on March 18, 1683, his first impulse was to survey the literature from Anaxagoras in antiquity to his own observations of 1668 to find references to similar phenomena.[49] To a surprising degree, early modern empirical inquiry was an archival science.

But not in the usual early modern sense of the word *archive*: medieval and early modern archives were usually institutional (pertaining to, e.g., the church, state, or municipality) or familial and largely legal in character. They preserved edicts, genealogies, court records, and, above all, titles and deeds to property, to be produced should dynastic legitimacy, ownership, tax revenues, or other rights be challenged.[50] When, for example, Leibniz foraged in the archives in the service of the House of Braunschweig-Lüneburg, it was in order to establish its credentials as the legitimate successor of the Guelf dynasty.[51] Early modern archives were bastions of authenticity, places of proofs and pedigrees. In contrast, the language used to describe what would now be called scientific archives was that of stored-up riches: "granaries," "warehouses," "treasuries." Collections of historiae and observationes were precious repositories (another favored early modern word[52]) to be drawn upon to make comparisons, extend inductions over past similar cases, and support generalizations. Like the diplomatic archives plumbed by nineteenth-century historians of the Ranke school, the sixteenth- and seventeenth-century scientific archives were sites of discovery and serendipity.

They were also provisions laid up for future inquirers. Astronomers and meteorologists, whose dependence on observational records stretched back into earliest antiquity,[53] were particularly conscious of the value of such legacies (which were often considered family property, handed down father to son, as in the case of the Cassini dynasty at the Paris Observatory). Tycho Brahe allowed only a privileged few access to his hoard of astronomical observations; the legal disputes concerning their ownership after his death were notorious.[54] The French astronomer Joseph-Nicholas Delisle traveled all over Europe buying up the books, observation journals, manuscripts, and correspondence of defunct astronomers, which he sold to the French crown in exchange for handsome annuities for himself, his secretary, and his assistant Charles Messier.[55] Even rough, badly made observations were considered valuable enough to be preserved for posterity. Jacques-Dominique Cassini IV pronounced

[49] Cassini, "Découverte de la Lumiere Celeste qui paroist dans le Zodiaque," *Mémoires de l'Académie Royale des Sciences, 1666–99*, 11 vols. in 14 (Paris, 1733), 8:179–278.

[50] For an overview, see Patrizia Angelucci, *Breve storia degli archivi e dell'archivistica* (Perugia, 2008), 29–58.

[51] Maria Rosa Antognazza, *Leibniz: An Intellectual Biography* (Cambridge, 2009), 230–3.

[52] On the etymology and early modern associations of *repertorium*, see Blair, *Too Much to Know* (cit. n. 28), 120.

[53] Daryn Lehoux, *Astronomy, Weather, and Calendars in the Ancient World* (Cambridge, 2007), 56–65, 101–13; on medieval astrometeorological observations, see Katharine Park, "Observation in the Margins, 500–1500," in Daston and Lunbeck, *Histories of Scientific Observation* (cit. n. 28), 15–44.

[54] Brahe, *Tycho Brahe's Description of His Instruments and Scientific Work* [*Astronomiae Instauratae Mechanica*, 1598], trans. and ed. Hans Raeder, Elis Strömgren, and Bengt Strömgren (Copenhagen, 1946), 108–10; John Robert Christianson, *On Tycho's Island: Tycho Brahe, Science, and Culture in the Sixteenth Century* (Cambridge, 2000), 302–3.

[55] E. Doublet, *Correspondance échangée de 1720 à 1739 entre l'astronome J.-N. Delisle et M. de Navarre* (Bordeaux, 1910), 7. The riches of Delisle's collection have since been dispersed across several archives, but some sense of their contents can be derived from the partial inventory still held by

some loose sheets of astronomical and meteorological observations made by the academician Sédileau in 1691–3 "uncertain" and "in rather bad order" but nonetheless urged that the Académie Royale des Sciences keep them: "However, original manuscripts of observations are always precious, they can provide clarification when compared with others, [and] consequently I believe that one would do well to preserve these."[56] In this spirit, the big, leather-bound observation journals begun by Cassini I on September 14, 1671, at the Paris Observatory were not only continued but also carefully annotated and corrected by his successors.[57] Who knew when an apparently trivial or even sloppy observation might turn out to be invaluable?

Overwhelmed by the vasty vastness of the universe of particulars awaiting investigation and sharply conscious of the time, labor, and expense involved in observing even a portion thereof, early modern inquirers often became possessive to the point of miserliness when it came to preserving even slipshod jottings, like those of Sédileau. Two classes of observations were particularly precious: daily astronomical and meteorological records, and firsthand descriptions of rare phenomena (e.g., an aurora borealis, a monstrous birth, or even cyclic events with long periods, such as the transits of Venus). These extremes of the mundane and the marvelous were alike in that they could never or only seldom be repeated. The English astronomer Edmond Halley was bitterly disappointed to have missed the first part of an aurora borealis on March 6, 1716, exceptionally visible in the London sky, and therefore to be forced to report the not always reliable observations of others: "Thus far I have attempted to describe what was seen, and am heartily sorry I can say no more as to the first and most surprizing Part thereof, which however frightful and amazing it might seem to the vulgar Beholder, would have been to me a most agreeable and wish'd for Spectacle; for I then should have contemplated *propriis oculis* all the several Sorts of Meteors I remember to have hitherto heard or read of."[58]

Yet utterly unspectacular daily weather readings were even more fleeting, as ephemeral as today and never to return. Under these circumstances, the old motto *carpe diem*, "seize the day," could powerfully motivate observers. When the events of the French Revolution threatened to interrupt the continuous series of weather observations conducted at the Paris Observatory since 1671, the astronomer Joseph-Jerôme de Lalande wrote a terse, peremptory, and, given how recently the Académie Royale des Sciences had been dissolved and Lavoisier guillotined by revolutionary decrees, bold letter to the Directory: "The Bureau of Longitudes, as charged by the law of the Observatory, must continue meteorological observations in the cellar of the Observatory; we request that you have the seals [blocking access] removed immediately."[59] These were the kinds of irreplaceable observations, quotidian or

the Paris Observatory: [Delisle], "Inventaire des livres d'astronomie," Bibliothèque de l'Observatoire de Paris, B5.14.

[56] Folder "Sédileau, Observations astronomiques depuis le 1er Novembre 1691 jusqu'au 4 Septembre 1693," in Pochette de séance 1693, Archives de l'Académie des Sciences, Paris. The annotations are signed "J. D. Cassini."

[57] See, e.g., the corrections (apparently by Jacques Cassini II, usually in red ink) inserted in the margins of the observational journals kept for 1671–4; Gian Domenico Cassini I, "Journal des observations faites à l'Observatoire, 1671–1674," Bibliothèque de l'Observatoire, Paris, AD 1–16.

[58] Halley, "An Account of the late surprizing Appearance of the *Lights* seen in the *Air*, on the sixth of March last, with an attempt to explain the Principal *Phaenomena* thereof," *Phil. Trans. Royal Soc. London* 29 (1714–6): 406–28, on 416.

[59] Lalande to the Directoire, 4 Prairial [there is no year, but the Directory held power 1795–9], Dossier Joseph-Jerôme de Lalande, Archives de l'Académie des Sciences, Paris.

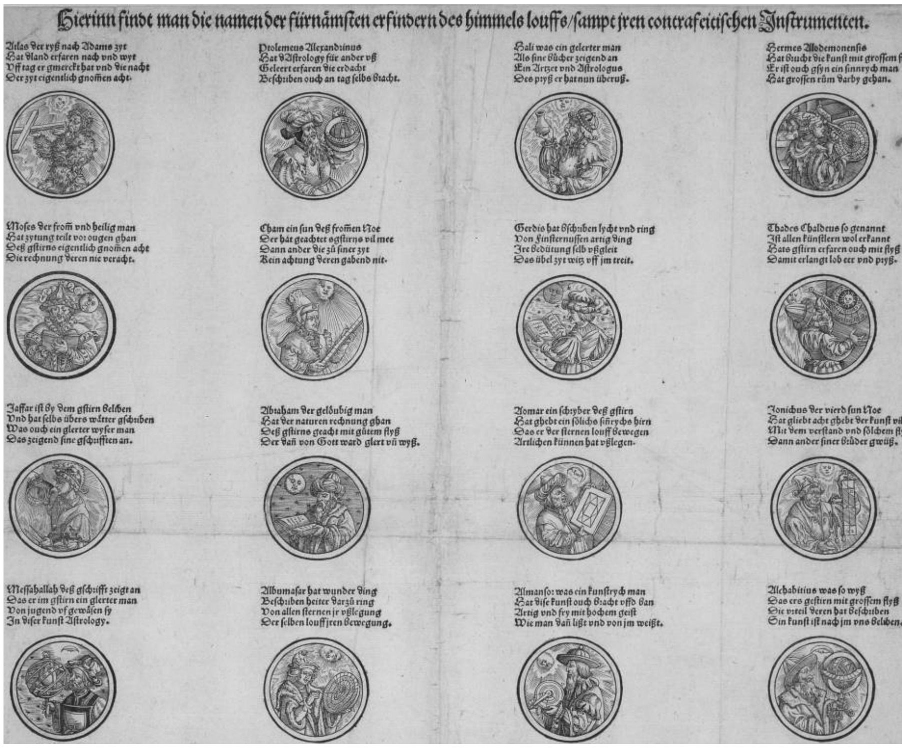


Figure 6. *A genealogy of famous astronomers. Heinrich Vogtherr the Elder and Jacob Ruf,* Hierinn findt man die Namen der fürnamsten Erfindern des Himmels Louffs *(1546). Copyright Staatliche Museum zu Berlin, Kupferstichkabinett, Inv. 140–1889. Reprinted by permission of the Staatliche Museum zu Berlin, Kupferstichkabinett.*

once in a blue moon, that were hoarded by families (and sometimes sold by heirs for a tidy sum to collectors like Delisle) and by institutions such as observatories and academies for perusal as future occasions might require.

The time dimension of these scientific archives avant la lettre extended into the past as well as into the future. The collaborators enlisted in the writing of early modern historiae and observationes included not only coeval correspondents and fellow academicians but also authors who survived only in books and manuscripts. Just as humanists lined their studies with portraits of illustrious predecessors since Plato, astronomers constructed genealogies of observers linking past and present (fig. 6).[60] Historians of science have noted the affective bonds that often united correspondents who exchanged specimens, images, and observations.[61] Joined in a common

[60] Anthony Grafton, "From Apotheosis to Analysis: Some Late Renaissance Histories of Classical Astronomy," in *History and the Disciplines: The Reclassification of Knowledge in Early Modern Europe*, ed. Donald Kelley (Rochester, N.Y., 1997), 261–76. See also Grafton, *Bring Out Your Dead: The Past as Revelation* (Cambridge, Mass., 2001), for parallels with Renaissance humanist construction of learned genealogies.

[61] For the early modern period, see, e.g., Florike Egmond, "Clusius and Friends: Cultures of Exchange in the Circles of European Naturalists," in *Carolus Clusius: Towards a Cultural History of a Renaissance Naturalist*, ed. Edmond, Paul Hoftijzer, and Robert Visser (Amsterdam, 2007), 9–48, and Pomata, "Observation Rising" (cit. n. 28).

undertaking and in a common enthusiasm for their subject matter, the members of these epistolary communities rang the changes on the register of friendship and linked-arm dedication to a noble goal. But behind the ranks of the living citizens of the republic of letters stood the dead, no longer regarded with the reverence due to demigods but rather with the fellow feeling (and at times, the asperity and rivalry) due to colleagues. We have already seen how early modern astronomical and medical observations could be treated either as private property with cash value or as a common good to be recompensed only by gratitude and glory.[62] Then as now, the republic of letters was located in a twilight zone between the realms of honor and lucre. In certain ways, the relationship with the dead was more intimate than that with the living.[63] Learned pen pals separated by mountains or oceans or warring religions might never meet. The dead, in contrast, were always at hand, as close as the books of one's own library, patiently awaiting a consultation—and unable to revenge a plundering.

THE HYBRID HERMENEUTICS OF READING AND SEEING

The resemblance between these two pieces of early modern learned furniture, the one designed for natural and medical specimens and the other for reading excerpts (figs. 7 and 8), is striking. Drawers further subdivided into compartments sorted mobile objects—rocks, scraps of paper—into orders that could be expanded and revised as further acquisitions dictated. Reading and seeing, collecting words and collecting things, were closely intertwined practices in the study of nature during this period. Observations recorded in words and images had to be intercalated with autopsia, and despite much rhetoric to the contrary, it was not always the case that the firsthand experience trumped the secondhand testimony delivered in books and records. A much more complex process of compilation, comparison, correction, and calibration brought together past descriptions and present experience. Sometimes the calibration was straightforward, if arduous, as when French astronomer Jean Picard traveled to the ruins of Tycho Brahe's Uraniborg to determine its coordinates in order to compare Tycho's observations with those made at the Paris Observatory.[64] Sometimes it was subtle, because interpretive, as when Cassini I mined ancient works of astronomy, meteorology, natural history, and history to find precedents for the strange celestial light he observed in the Parisian skies in the spring of 1683.[65] In contrast to observations preserved because they were unusual or unrepeatable, multiple observations of what were arguably the same or similar objects posed challenges of

[62] Once again, there are strong analogies with humanist collections of reading notes and excerpts; Blair, *Too Much to Know* (cit. n. 28), 63, 188–202.

[63] Niccolò Machiavelli famously wrote (in a 1513 letter to Francesco Vettori) about how he donned his finest robes before entering his library in order to be worthy of the company of the dead dignitaries assembled on his shelf. On more ambivalent attitudes of humanists to ancient authors, see Anthony Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800* (Cambridge, Mass., 1991), 23–46.

[64] Kurt Møller Pedersen, "Une mission astronomique de Jean Picard: Le voyage d'Uraniborg," in *Jean Picard et les débuts de l'astronomie de précision au XVIIIe siècle*, ed. Guy Picolet (Paris, 1987), 175–203.

[65] Gian Domenico Cassini I, "Nouveau phenomene rare et singulier, d'une lumiere Celeste, qui a paru au commencement du Printemps de cette Année 1683," *Mémoires, 1666–99* (cit. n. 49), 8: 179–278.

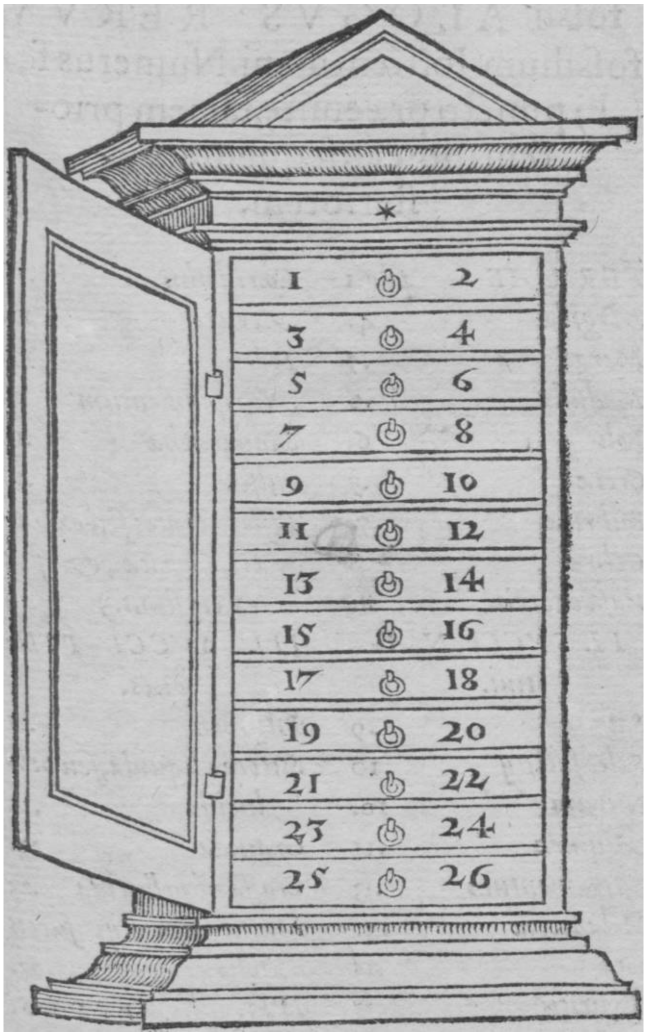


Figure 7. *Cabinet for mineral specimens. Johannes Kentmann,* Nomenclatura Rerum Fossilium *(Zurich, 1565), sig. a. Reprinted by permission of the Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Abteilung Historische Drucke in sign Mq 211: P.16.*

surfeit rather than dearth: how to combine many, sometimes divergent perspectives into one.[66]

Early modern reading practices reinforced the exigencies of so little time, so much to observe in order to preserve the library alongside the field, the observatory, and the laboratory as a research site. Past observations were not just physically contained in books and manuscripts; they were *read* as books and manuscripts were. It is not enough for the sciences of the archive to store information; they must also invent ways to use it. The ways of reading cultivated by early modern savants were as distinctive as today's computer search algorithms and just as consequential for

[66] These problems became acute when continuous and repeated observation became the norm, first in astronomy in the sixteenth century and in almost all other sciences by the early eighteenth century; Lorraine Daston, "The Empire of Observation, 1600–1800," in Daston and Lunbeck, *Histories of Scientific Observation* (cit. n. 28), 81–113, on 91–5.

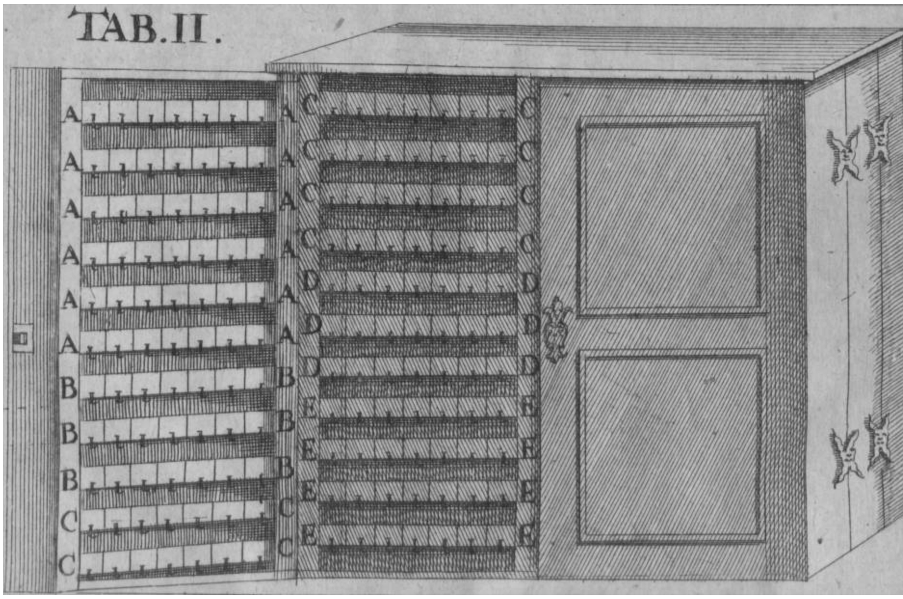


Figure 8. *Cabinet for reading excerpts. Vincent Placcius,* De Arte Excerpendi: Vom gelahrten Buchhalten *(Hamburg, 1689), tab. II. Reprinted by permission of the Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Abteilung Historische Drucke in sign A.1998:R.*

what counted as knowing and knowledge. Many, though not all, early modern naturalists had been trained in applying humanist techniques to texts: making excerpts, taking notes, assembling commonplace books and other collections, compiling indexes.[67] Some of these methods for reading books were retooled for reading the book of nature.

The habit of keeping a commonplace book in which to record excerpts from reading could, for example, blend seamlessly with that of noting down observations. The keeping of commonplace books of especially moral adages culled from the reading of classical authors was a pillar of early modern education in rhetoric. Schoolboys were enjoined to fill notebooks specially designated for this purpose with choice morsels from their reading, as an aide-mémoire and source of apposite quotations and sententiae in set themes and speeches.[68] In contrast to the medieval florilegium, which was recommended but not mandatory, the Renaissance commonplace book, after the advent of printing made many more texts available, became what Ann Moss has called the "interpretative grid" for schoolboy reading and classroom dictation, "a paradigm for reading analysis" throughout learned Europe in the sixteenth century.[69] During the early modern period, numerous instructions for the keeping of well-ordered commonplace books were published, recommending various systems

[67] See the excellent account of these techniques of "scholarly information management" in Blair, *Too Much to Know* (cit. n. 28).

[68] Sister Joan Marie Lechner, *Renaissance Concepts of the Commonplaces* (Westport, Conn., 1962), 153–99.

[69] Moss, *Printed Commonplace Books and the Structuring of Renaissance Thought* (Oxford, 1996), 136.

of indexes, headings, and cross-references, entrenching the practice still further.[70] Blair has shown in the case of Jean Bodin how these methods could be applied to the composition of a work in natural philosophy; Johns has described their role in the experiments performed and recounted at the early Royal Society.[71]

A few examples have come to light that also point to an intimate connection between the reading practices of the commonplace book and those of observing nature; more research on the *Nachlässe* of early modern naturalists will probably yield more. Ogilvie has described how the Zurich humanist and naturalist Conrad Gessner kept commonplace books both for his botanical observations (including dried specimens) and for his reading and correspondence. He filed all letters he received according to topic, sometimes cutting them up and distributing the clippings topically.[72] John Locke kept his daily meteorological observations (arranged in tabular form) in the same bound commonplace book, entitled "Adversaria Physica" and dated 1660, as his handwritten excerpts from his reading in Latin, French, and English. Scattered amid excerpts from the works of Isaac Newton, Robert Boyle, Christiaan Huygens, and numerous other natural philosophers are recipes, both medical and culinary (e.g., for "Pudding. You've your Pann of ye bignesse you'l have it . . ."), useful information (e.g., a list of the best French pears, in descending order of deliciousness), and Locke's own observations, initialed "JL" (e.g., on thunder and lightning). Locke's weather observations for the period 1666–1703 were recorded at the back of this volume; there is a hint (the outline of a pressed plant) that he also used the "Adversaria Physica" as a makeshift herbarium.[73] For Gessner and Locke, there seemed to be little distinction between observations they had conducted themselves and excerpts they had made from written sources: all were extracted and filed, bits of books and experience cut out and reassembled in new patterns.

Both reading and observing were first and foremost exercises in seeing. Intermediate between the word and the thing was the image, or even, in the case of the botanical herbarium, the dried plant flattened on a page and bound into a book. Recent work by historians of art and science on early modern collections of images hint at the fungibility of specimens and images, which were gathered, classified, and exchanged in similar ways.[74] Woodcuts and engravings could mediate between verbal descriptions and the immediate and sometimes overwhelming experience of raw nature: the cornucopia of novel flora and fauna of the tropics, the gore and mess of the dissected

[70] Ibid., 186–214. Among the most famous of these instructions was [John Locke], "Méthode nouvelle de dresser des recueils," *Bibliothèque universelle et historique* 2 (1686): 315–28; see Richard Yeo, "John Locke's 'New Method' of Commonplacing: Managing Memory and Information," *Eighteenth Century Thought* 2 (2004): 1–38.

[71] Ann Blair, "Annotating and Indexing Natural Philosophy," in *Books and the Sciences in History*, ed. Marina Fresca-Spada and Nicholas Jardine (Cambridge, 2000), 69–89; Johns, "Reading and Experiment" (cit. n. 28).

[72] Ogilvie, *Science of Describing* (cit. n. 28), 180–1.

[73] John Locke, "Adversaria Physica," MS Locke d.9, Bodleian Library, Oxford, on 240, 236, 42. The table of weather observations (running backward and unpaginated) is at the back of the volume; the imprint of the plant is on 109.

[74] See, e.g., David Freedberg, *The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Natural History* (Chicago, 2002); Alessandro Alessandrini and Alessandro Ceregato, *Natura Picta: Ulisse Aldrovandi* (Bologna, 2007); Daniela Bleichmar, "The Geography of Observation: Distance and Visibility in Eighteenth-Century Botanical Travel," in Daston and Lunbeck, *Histories of Scientific Observation* (cit. n. 28), 373–95; Susan Dackerman, ed., *Early Modern Prints and the Pursuit of Knowledge* (Cambridge, Mass./New Haven, Conn., 2011).

human corpse in the anatomy theater, the delicate and fleeting effects of phosphors. Sachiko Kusukawa has described how the students who attended Andreas Vesalius's anatomy lectures at the University of Padua in the mid-sixteenth century triangulated between the corpse being demonstrated in front of them, the much more distinct image of the same organs in the textbook they simultaneously held in their hands, and the oral and written descriptions of the object.[75] By reading both book and book of nature side by side, the novice gradually developed an expert eye for the essential, the normal, and the typical. Halfway between reading and observing, the study of printed images linked the skills that made texts legible and nature intelligible.[76]

Something of how this process of visual calibration worked can be gleaned from the working notes of the huge, expensive, and never-completed project for a *Histoire des plantes* launched by the Paris Académie Royale des Sciences in 1667.[77] This project attempted to calibrate the senses of botanists and artists: by teaching them how to read, see, taste, and smell in unison, multiple observers would, it was hoped, synchronize themselves—and not only with each other, but also with the generations of botanists who had preceded them. Their working tools were live plants, dried herbarium specimens, drawings and engravings, and books. To describe a plant properly involved looking (as well as tasting and smelling), drawing, and also reading all previous published descriptions, textual and visual. In contrast to the humanist techniques for managing texts (excerpting, compiling, glossing), the Parisian academicians sought a hybrid hermeneutics that merged the testimony of botanists since Theophrastus and Dioscorides with that of their own senses.

Instilling such a collective hermeneutics could only have been contemplated within a framework of close coordination and supervision. The first line of botanist Denis Dodart's 1676 publication of the preliminary results of the project underscored its collective nature: "This book is the work of the entire Academy."[78] But the ambitions of the *Histoire des plantes* overflowed the bounds of what the academicians could contribute in the way of their own observations and experiments. As Dodart explained, he and his fellow academicians aimed to provide descriptions and figures of all plants identified by both ancient and modern botanists, in order to correct errors, clarify conflated identifications, and distinguish not only all known species unambiguously from one another but also from as-yet-unknown species that might be discovered in the future.[79] Moreover, plants would be described on the basis not only of the external appearance of all their parts (flower, leaf, bud, seed, root, etc.)

[75] Kusukawa, *Picturing the Book of Nature: Image, Text, and Argument in Sixteenth-Century Human Anatomy and Medical Botany* (Chicago, 2012), 198–227; Kusukawa, "The Uses of Pictures in the Formation of Learned Knowledge: The Cases of Leonhard Fuchs and Andreas Vesalius," in *Transmitting Knowledge: Words, Images, and Instruments in Early Modern Europe*, ed. Kusukawa and Ian Maclean (Oxford, 2006), 73–96.

[76] On the role of scientific atlases in calibrating ways of seeing, see Daston and Galison, *Objectivity* (cit. n. 20), 19–26.

[77] Claude Perrault sketched out the project at meetings of the Académie Royale des Sciences in January 1667: "Projet pour la Botanique," *Procès-Verbaux* 1 (22 décembre 1666–avril 1668): 30–8; Perrault's original manuscript, which diverges in some places from the fair-hand minutes of the meeting, is preserved in the Pochette de séance for January 15, 1667. Records of the chemical analyses performed on plants are preserved in the Fonds Bordelin, Archives de l'Académie des Sciences, Paris. The fortunes of the project are described in Stroup, *Company of Scientists* (cit. n. 27).

[78] Dodart, "Avertissement," in *Mémoires pour servir à l'histoire des plantes* (Paris, 1676), n.p.

[79] Dodart, *Mémoires* (cit. n. 78), 3.

but also of their internal structures, examined microscopically, and of their chemical composition.

This was an undertaking that required the constant consultation of all extant botanical literature and further invited "savants and other persons expert in these matters to communicate their thoughts to us," with the promise that all those who had "contributed something to the perfection of this work" would be thanked by name in future publications.[80] And these were only the named participants in the project. At least as crucial to the project's success were the efforts of its artists, especially Abraham Bosse, Nicolas Robert, and Louis de Chastillon, whose names appeared only in small print in the lower corner of the plates. Yet the *Histoire des plantes* was in part inspired by Robert's opulent illustrations of flowering plants for Gaston d'Orléans, and aside from Dodart's 1676 *Mémoires*, the sole publication ever to issue forth from the mammoth project was of the 319 plates, produced at a cost of (by 1700) more than 25,000 livres and published without text in part in 1719 and in full in 1788.[81] Most of the surviving manuscripts concerning the project appear to have been Dodart's minute instructions to the artists, of whom he sometimes despaired, and other anonymous assistants employed to make observations, write descriptions, and draw plants.[82]

These unpaginated loose sheets, each headed with the name of a plant, take the form of numbered queries, corrections, and instructions, usually in a fair hand (presumably dictated), with occasional replies in another hand. So, for example, under "Grande Absinthe" (fig. 9; replies, in a different hand, are here rendered in italics):

> I. The seed? by the Microscope.
> II. Of how many florets is the flower composed? *around 50 or 60.*
> III. The leaf and the bud are they truly furry? look at under the magnifying glass. *they are covered with cotton which renders them white-ish.*
> IV. The root is it really bitter? *the bitterness is not extreme but it is piquant.*
> V. Distilled water.
> VI. What Absinthes are in the Royal Garden?[83]

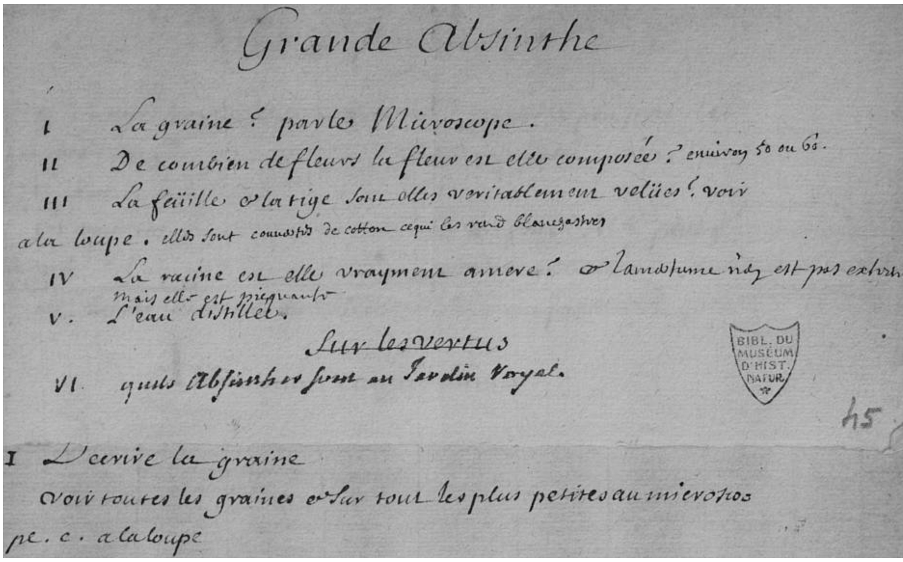
The style of seeing and describing enforced by these queries and instructions was unrelentingly comparative: artists and assistants were sternly reminded to consult all previous descriptions and figures in previous botanical works before beginning their own; the single most frequent exhortation was to repeat an observation, either to

[80] Ibid., sig. Ar.

[81] Perrault mentions the Orléans collection explicitly: "Suivant cette methode on peut travailler à une histoire des plantes generalle et acomplie qu'il sera facile d'enrichir et rendre tout a fait magnifique et Royale en continuant et achevant de travail qui a été commencé par l'ordre de feu Mr. le Duc d'Orleans et faisant graver beaux portraits des plantes qu'il nous a laissez si naivement tiré." Perrault, "Projet pour la Botanique," in Pochette de séance, January 15, 1667 (cit. n. 77), n.p. On the subsequent publication history of the plates, see *Recueil des plantes, gravées par ordre de Louis XIV* (Paris, 1788), 1:v; and on the vellums, see Yves Laissus, "Les plantes du roi: Note sur un grand ouvrage de botanique préparé au XVIIe siècle par l'Académie Royale des Sciences," *Rev. Hist. Sci.* 22 (1969): 193–236.

[82] Camille Frémontier and Alice Stroup, "Les sources iconographiques de l'histoire de l'Académie Royale des Sciences," in *Histoire et mémoire de l'Académie des Sciences*, ed. Eric Brian and Christiane Demeulenaere-Douyère (Paris, 1996), 379–93. Some of Dodart's manuscript annotations refer to the observations of "J. B."—possibly the academician Jacques Borel (also sometimes known as Borelly), who was also involved in the *Histoire des plantes*.

[83] "Grande Absinthe," in "Notes sur l'*Histoire des plantes*," MS 450, Bibliothèque du Muséum national d'histoire naturelle, Paris.


Grande Absinthe

I La graine ? par le Microscope.
II De combien de fleurs la fleur est elle composée ? environ 50 ou 60.
III La feüille & la tige sont elles veritablement velües ? voir
a la loupe. elles sont couvertes de cotton ce qui les rend blanchastres
IV La racine est elle vrayment amere ? & l'amertume n'est pas extreme
mais elle est piquante
V. L'eau distillee.
Sur les vertus
VI quels Absinthes sont au Jardin Royal.

BIBL. DU MUSEUM D'HIST. NATUR.

45

I Decrire la graine
voir toutes les graines & sur tout les plus petites au microsco
pe. c. a la loupe

Figure 9. *"Grande Absinthe" (cit. n. 83) with numbered queries and replies. Reprinted by permission of the Bibliothèque centrale du Muséum national d'histoire naturelle, Paris, MS 450.*

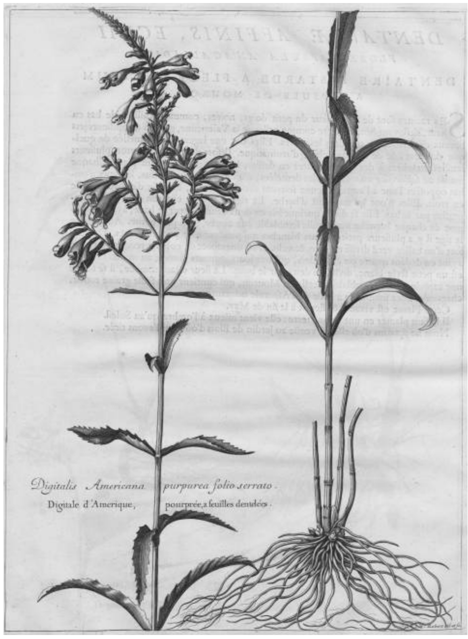
check that of a predecessor or to sharpen one's own. At the bottom of the queries to "Aconitum hyemale luteum bulbosum" followed a firm injunction:

> I. Do not make any description of a Plant already described without having read the best description, or at least [not] without confronting it with the one [already] made.
> II. Try to read all the descriptions in order to verify them from nature [*sur la nature*], and to compare them with ours.[84]

The copious and exacting instructions, paired with the laconic and sometimes dissenting replies, bear witness to a struggle between ways of seeing, touching, smelling, and tasting. The syntheses achieved by the *Histoire des plantes* depended on such comparisons, corrections, and repetitions (fig. 10). Observation shuttled between texts, images, and plants and back again until all three coalesced. These were the practices and challenges that anchored even the most militantly empirical naturalists to the library, as well as to the herbarium and museum. There they found armies of collaborators waiting on the shelf to help with the challenge of observing nothing less than all the phenomena in the universe; there they exercised the ways of seeing, parsing, recording, and ordering that made sense of the written page, the printed image, and the prodigious variety of nature.

The hybrid hermeneutics of reading and seeing, and of melding multiple and multimedia observations into a single definitive one, has its own history. Andrew Mendelsohn has shown how the Société Royale de Médecine used refined editing techniques to synthesize hundreds of meteorological and medical observations sent in

[84] "Aconitum hyemale luteum bulbosum" (see also "Aconitum pyramidale multiflorum"), in "Notes sur l'*Histoire des plantes*" (cit. n. 83).



DIGITALIS AMERICANA
PVRPVREA, FOLIO SERRATO.

DIGITALE D'AMERIQUE, POURPRE'E, A FEÜILLE DENTELE'E.

LA racine de cette Plante eſt blanche & fibreuſe. Elle pouſſe une ſeule tige, haute de quatre pieds, quarrée, noüeuſe en diſtances égales d'un pouce & demy, & moüelleuſe. Les feüilles ſont longues de trois pouces, & larges d'un demy-pouce, fort pointuës, dentelées, liſſes, d'un vert-brun, avec une coſte blanche. Elles ſortent des nœuds de la tige, deux à deux oppoſées l'une à l'autre, en ſorte que celles d'un nœud croiſent celles de l'autre. Du haut de la tige naiſſent des branches oppoſées deux à deux, les unes croiſant les autres, reveſtuës vers le haut de quantité de cornets gris-de-lin, longs environ d'un pouce, eſtroits dans leur origine, d'où ils vont s'eſlargiſſant juſques au bout, où ils ſont diviſez en deux levres. L'inferieure eſt coupée en trois parties. Celle du milieu eſt la plus grande, & tachetée de pourpre comme à la Digitale vulgaire. A la levre ſuperieure ſont attachez quatre filets couleur de citron, qui naiſſent du fonds de la fleur, & ne s'en deſtachent que vers l'extremité. Ils ont chacun un ſommet de la meſme couleur. Chaque fleur naiſt d'un calice diviſé en cinq, lequel venant à ſe groſſir, eſt remply de quatre graines brunes triangulaires.

La racine paroiſt d'abord inſipide. Mais quand on l'a beaucoup maſchée, elle fait ſentir une acreté conſiderable, meſlée de quelque amertume. Les feüilles auſſi ſont aſſez acres, mais on n'y remarque que cette ſaveur.

Cette Plante eſt vivace. Elle fleurit en Juillet.

Elle vient également bien à l'ombre & au ſoleil, mais il luy faut une bonne terre. On la peut ſemer en Automne en pleine terre, ou ſur couche au Printemps.

Figure 10. *Description and figure of* Digitalis americana*. The text contains a gustatory as well as a visual description of the plant: "The root at first seems insipid, but when much chewed, it exudes considerable acidity, mixed with some bitterness." Dodart,* Mémoires *(cit. n. 78), 79. Reprinted by permission of the Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Abteilung Historische Drucke in sign Lw2250.*

by provincial doctors; Jed Buchwald has described in detail how discrepant measurements were dealt with before the adoption of probabilistic methods like that of least squares.[85] But we still lack anything like the detailed and textured histories now available for early modern reading practices (or the senses) about how scientific reading and seeing were schooled in unison as new methods of combining past and present observations, text and autopsia, developed. What evidence we do have suggests that this history was dynamic, as rich in innovation and sophistication as the evolving hermeneutics of the nineteenth-century historians who perfected *Quellenkritik*, the twentieth-century informatics specialists who put together databases, and the twenty-first-century computer scientists who devise search algorithms.

One example from the history of taxonomy must suffice here. When the comparative anatomist Georges Cuvier sought to settle the question of whether mammoth remains corresponded to any still-extant species, he examined fossils, dissected elephants—and read books, lots of them: Polybius and Titus Livy, Linnaeus and Buffon, Athanasius Kircher and Felix Platter. Cuvier was critical of his sources, especially the older ones: "As one approaches our epoch, observations become more

[85] Mendelsohn, "The World on a Page: Making a General Observation in the Eighteenth Century," in Daston and Lunbeck, *Histories of Scientific Observation* (cit. n. 28), 396–420; Buchwald, "Discrepant Measurements and Experimental Knowledge in the Early Modern Era," *Arch. Hist. Exact Sci.* 60 (2006): 565–649.

exact [*positives*]."[86] Yet he relied upon them to make comparisons, correct errors, sharpen vague reports, and canvass all the locales where fossil pachyderm remains had been discovered to date. His voluminous survey of the literature (which he regretted was not still more thorough) allowed him to conclude that a "prodigious quantity of such bones" had already been discovered with a distribution from Siberia to the Americas, mostly in alluvial basins that also yielded fossils of rhinoceroses, antelopes, horses, and marine animals.[87]

Cuvier's evaluation of the quality of past observations was that of a connoisseur, cautious and discerning. His reading practices were no longer those of the humanist compendium and commonplace book, indiscriminately jumbling together reading excerpts and observations. He drew a bold line between his own observations, those of witnesses whom he trusted (e.g., Johann Friedrich Blumenbach), and those of witnesses he did not (e.g., Peter Simon Pallas). Particularly notable is his reinterpretation of past observations in light of present knowledge: for example, he explained how Platter could have mistaken the bones dug up in Lucerne in 1577 for those of a human giant (which the city then proudly emblazoned on its coat of arms), pointing out that the missing teeth prevented him from identifying the remains as those of a quadruped.[88] But even as he read his sources against the grain, he did read them, carefully, comprehensively, and fruitfully. Along with the museum, the dissecting table, and the field excavation, the library was still an indispensable site of research for the most advanced sciences of the early nineteenth century—and long thereafter (fig. 11).

Although the organization of observer networks and the emergence of new reading and observing practices in the late eighteenth and early nineteenth centuries altered the relationship of scientific inquiry to book learning,[89] the library remained an indispensable site of natural history, supplemented by mushrooming collections of specimens at institutions such as the Paris Muséum d'histoire naturelle, the British Museum, Kew Gardens, and the New York American Museum of Natural History.[90] Especially in systematics, as Robert Kohler has noted, rules of nomenclature "oblige those who would name a new species to actively engage the literature back to the Linnaean big bang."[91] Once the practice of linking species names to individual type

[86] Cuvier, *Recherches sur les ossemens fossiles, où l'on rétablit les caractères de plusieurs animaux dont les révolutions du globe ont détruit les espèces*, 2nd ed. (Paris, 1821–4), 1:104. On the context of Cuvier's investigations of pachyderms, see Martin J. S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago, 1997), 13–41; Claudine Cohen, *The Fate of the Mammoth: Fossils, Myth, and History* (1994), trans. William Rodarmor (Chicago, 2002), 105–24.

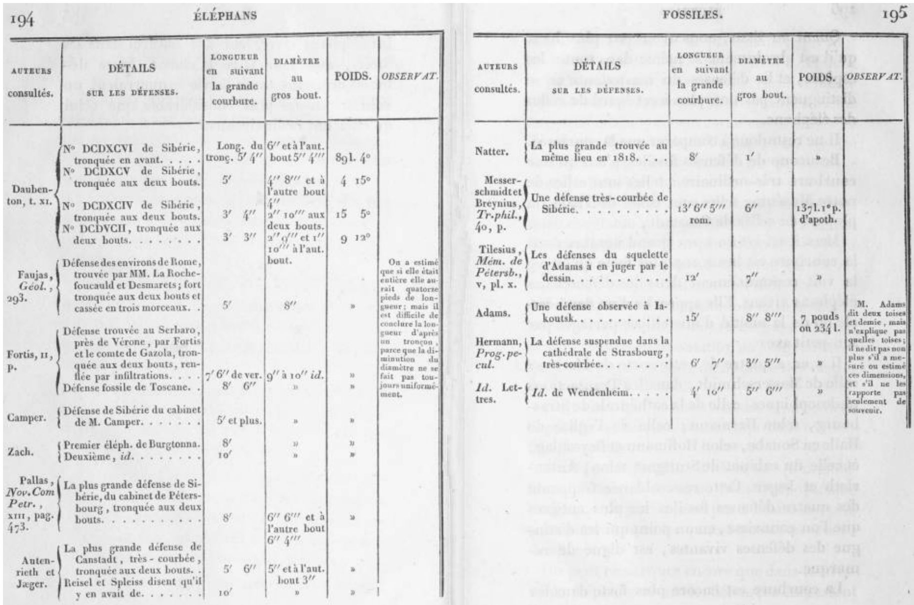
[87] Cuvier, *Recherches* (cit. n. 86), 1:159, 201.

[88] Ibid., 1:113.

[89] Mendelsohn, "World on a Page" (cit. n. 85); Anne Secord, "Coming to Attention: A Commonwealth of Observers during the Napoleonic Wars," in Daston and Lunbeck, *Histories of Scientific Observation* (cit. n. 28), 421–44.

[90] On the growth of these collections and their impact on nineteenth-century taxonomy, see (for the British Museum) Gordon McOuat, "Cataloguing Power: Delineating 'Competent Naturalists' and the Meaning of Species in the British Museum," *Brit. J. Hist. Sci.* 34 (2001): 1–28; (for American institutions) Robert E. Kohler, *All Creatures: Naturalists, Collectors, and Biodiversity, 1850–1950* (Princeton, N.J., 2006); (for Kew Gardens) Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science* (Chicago, 2008); and (for the Muséum d'histoire naturelle) Pierre-Yves Lacour, "La république naturaliste: Les collections françaises d'histoire naturelle sous la Révolution, 1789–1804" (PhD diss., European Univ. Institute, 2010).

[91] Kohler, "Reflections on the History of Systematics," in *Patterns in Nature: Historical and Conceptual Foundations of Systematics*, ed. Andrew Hamilton (Berkeley and Los Angeles, 2012), 16–37. I am grateful to Professor Kohler for allowing me to read his essay in manuscript.



194 ÉLÉPHANS

AUTEURS consultés.	DÉTAILS SUR LES DÉFENSES.	LONGUEUR en suivant la grande courbure.	DIAMÈTRE au gros bout.	POIDS.	OBSERVAT.
Daubenton, t. XI.	N° DCDXCVI de Sibérie, tronquée en avant. . . .	Long. du tronç. 5′ 4″	6″ et à l'aut. bout 5″ 4‴	89 l. 4°	
	N° DCDXCV de Sibérie, tronquée aux deux bouts.	5′	4″ 8‴ et à l'autre bout 4″	4 15°	
	N° DCDXCIV de Sibérie, tronquée aux deux bouts.	3′ 4″	2″ 10‴ aux deux bouts.	15 5°	
	N° DCDVCII, tronquée aux deux bouts.	3′ 3″	2″ 9‴ et 1″ 10‴ à l'aut. bout.	9 12°	
Faujas, *Géol.*, 293.	Défense des environs de Rome, trouvée par MM. La Rochefoucauld et Desmarets; fort tronquée aux deux bouts et cassée en trois morceaux. .	5′	8″	»	On a estimé que si elle était entière elle aurait quatorze pieds de longueur; mais il est difficile de conclure la longueur d'après un tronçon, parce que la diminution du diamètre ne se fait pas toujours uniformément.
Fortis, II, p.	Défense trouvée au Serbaro, près de Vérone, par Fortis et le comte de Gazola, tronquée aux deux bouts, renflée par infiltrations. . . .	7′ 6″ de ver.	9″ à 10″ *id.*	»	
	Défense fossile de Toscane. .	8′ 6″	»	»	
Camper.	Défense de Sibérie du cabinet de M. Camper.	5′ et plus.	»	»	
Zach.	Premier éléph. de Burgtonna.	8′	»	»	
	Deuxième, *id.*	10′	»	»	
Pallas, *Nov. Com Petr.*, XIII, pag. 473.	La plus grande défense de Sibérie, du cabinet de Pétersbourg, tronquée aux deux bouts.	8′	6″ 6‴ et à l'autre bout 6″ 4‴	»	
Autenrieth et Jæger.	La plus grande défense de Canstadt, très-courbée, tronquée aux deux bouts. .	5′ 6″	5″ et à l'aut. bout 3″	»	
	Reisel et Spleiss disent qu'il y en avait de.	10′	»	»	

FOSSILES. 195

AUTEURS consultés.	DÉTAILS SUR LES DÉFENSES.	LONGUEUR en suivant la grande courbure.	DIAMÈTRE au gros bout.	POIDS.	OBSERVAT.
Natter.	La plus grande trouvée au même lieu en 1818. . . .	8′	1′	»	
Messerschmidt et Breynius, *Tr. phil.*, 40, p.	Une défense très-courbée de Sibérie.	13′ 6″ 5‴ rom.	6″	137 l. 1° p. d'apoth.	
Tilesius, *Mém. de Pétersb.*, V, pl. X.	Les défenses du squelette d'Adams à en juger par le dessin.	12′	7″	»	
Adams.	Une défense observée à Iakoutsk.	15′	8″ 8‴	7 pouds ou 234 l.	M. Adams dit deux toises et demie, mais n'explique pas quelles toises; il ne dit pas non plus s'il a mesuré ou estimé ces dimensions, et s'il ne les rapporte pas seulement de souvenir.
Hermann, *Prog. pecul.*	La défense suspendue dans la cathédrale de Strasbourg, très-courbée.	6′ 7″	3″ 5‴	»	
Id. Lettres.	*Id.* de Wendenheim.	4′ 10″	5″ 6‴	»	

Figure 11. *Synoptic chart of past observations of elephant fossils. Georges Cuvier,* Recherches sur les ossemens fossiles, *4th ed. (Paris, 1834), 2:194. Reprinted by permission of the Max Planck Institute for the History of Science, Berlin.*

specimens was enshrined in early twentieth-century international codes of botanical and zoological nomenclature, engagement with the literature could, in the absence of a designated holotype, extend to manuscript research in the Nachlass of the first naturalist to identify a new species in order to establish at least a lectotype.[92] Keeping words firmly attached to things—in this case, names to species—required feats of collective scientific memory that stretched centuries back into the past.

THE ARCHIVES OF THE FUTURE

Naturalists routinely embraced their predecessors but rarely their successors in their imagined community of collaborators. Astronomers were also avid curators (and sharp critics) of past observations, often with an undertone of sympathy even for efforts they judged to be flawed or obsolete. When Picard journeyed from Paris to the Danish island of Hven in 1671, he was firmly convinced that the accuracy of the Paris Observatory had surpassed that achieved by Tycho at Uraniborg a century earlier. Nevertheless, he was shocked to find the once-celebrated observatory in ruins: "I could not without indignation view this famous place, which will be talked about for as long as there are astronomers, filled with the old carcasses of animals like some foul rubbage-heap."[93]

[92] See W. Greuter et al., eds., *The International Code of Botanical Nomenclature* (Saint Louis Code, 1999), chap. 2, sec. 2, art. 9, recommendation 9A, available on the website of the Botanischer Garten und Botanisches Museum Berlin-Dahlem, http://www.bgbm.org/iapt/nomenclature/code/saintlouis/0000st.luistitle.htm (accessed 3 January 2011); Daston, "Type Specimens" (cit. n. 8), 170–7.
[93] Quoted in Pedersen, "Mission astronomique de Jean Picard" (cit. n. 64), on 179.

For as long as there are astronomers: how long would that be? The superhuman scale of celestial phenomena demanded communities of observers that were more ancient and more enduring than any human civilization in history. If early modern astronomers had projected their virtual communities deep into the past, their nineteenth-century counterparts vaulted into the far future. Not content simply to preserve the archive inherited from ancient observers in Mesopotamia, India, and China, they also aimed to create an archive for the astronomers thousands of years hence. The most ambitious of these archives for the future was the Carte du ciel or Great Star Map, an international collaboration of observatories launched in 1887 and ended (though not completed) by the International Astronomical Union in 1970, which aimed to compile a complete photographic map of the sky with all stars down to fourteenth magnitude (and a catalog down to eleventh magnitude, not completed until 1964).[94] The popular scientific press described the undertaking in the awed tones reserved for the Egyptian pyramids or the greatest medieval cathedrals: "Thus the science of the nineteenth century will bequeath to posterity an unimpeachable and imperishable record of the starry sky, which, in future centuries, will serve as a certain foundation for the solution of the grand problem of the constitution of the universe."[95] The astronomers themselves were hardly less modest and a great deal more practical: "This result [a new method for encasing the astrophotographs in glass] would have an enormous importance for the project, since it would assure the perfect conservation of images that we want to will to the astronomers of the year 3000 at least, inasmuch as today we do not know whether the chemical coating deposited on the glass will remain eternally unalterable."[96] Civilizations might rise and fall, but at least until the year 3000, there would be astronomers who would appreciate the archives prepared by their predecessors.

An imagined community that transcends time is one of the preconditions for the sciences of the archives. Another is the conviction that information about empirical particulars is intrinsically valuable and worth saving: either because the observations are part of a time series, like those of the daily weather or planetary positions, or because the phenomena are rare, like a supernova or an omega-minus particle in a bubble chamber, or just because there is not world enough and time to observe all the universe contains. Under these circumstances, observations will be not only collected but also preserved. The material and institutional underpinnings of transmission vary by historical epoch, from baked clay cuneiform tablets to optical discs made of silver and aluminum alloys, and from hereditary scribal classes to great national and university libraries. Some media are more durable than others—incunabula printed on parchment are still legible after over four centuries, whereas the estimated lifetime of a compact disc is thirty years—but all records depend on cultural will for their preservation and accessibility, as well as for the investment of labor and resources

[94] On the Carte du ciel see Suzanne Débarat, J. A. Eddy, H. K. Eichhorn, and A. R. Upgren, eds., *Mapping the Sky: Past Heritage and Future Directions* (Dordrecht, 1988); Théo Weimer, *Brève histoire de la Carte du ciel en France* (Paris, 1987); and Jérôme Lamy, ed., *La Carte du ciel: Histoire et actualité d'un projet scientifique international* (Paris, 2008). Correspondence relating to the project is available in Ileana Chinnici, *La Carte du ciel: Correspondence inédite conservée dans les Archives de l'Observatoire de Paris* (Paris, 1999).

[95] Camille Flammarion, "Le congrès astronomique pour la photographie du ciel," *Revue d'astronomie populaire, de météorologie et de physique du globe* 6 (1887): 161–9, on 169.

[96] E. B. Mouchez to David Gill, 30 April 1887, Observatoire de Paris, MS IV.A, "Comité international de la Carte du Ciel," carton 7.

needed to make them in the first place. Some sciences of the archive may exploit information not originally intended to serve their purposes, as, for example, historical demographers use parish records of births and deaths. Yet the effect of such serendipitous troves of data is usually to strengthen the conviction among scientists that special measures should be taken to preserve them (on microfiche, by digitalization, on backup servers, or even in fireproof vaults), rather than to trust to finder's luck and investigative ingenuity in the future. The sciences of the archive create traditions as durable as those of the Vatican.

But it is not enough to insure material transmission and institutional stability—the library, whether physical or virtual,[97] still nestled at the heart of the laboratory and the observatory. Traditions must be continually reinterpreted in light of present needs and notions in order to survive. In the humanities, this is the role of commentary and exegesis. Do the sciences of the archive cultivate analogous practices? The early modern hermeneutics of reading and seeing described above was one such practice of bringing past and present together but by no means the only one. New ones are constantly being invented—for example, in the construction and mining of databases.[98] In the early modern case, the practices of reading the book of nature depended heavily on older practices of reading books, but by the late eighteenth and early nineteenth centuries, at least some sciences of the archives had developed ways of sifting and synthesizing observations that were specific to discipline and sensitive to historical dynamics: witness Picard's and Cuvier's view that the accuracy of observation in their respective disciplines had advanced and that older observations must therefore be used with care. Yet the overwhelming sense of historicity that engulfed the humanities in the nineteenth and twentieth centuries, and that transformed the ancient methods of commentary and exegesis into exercises in historical contextualization, seem to have left the sciences of the archives largely untouched. They pursue history in science without history of science.

History *in* science differs from most other kinds of history by its curious indifference to the contours of time. Historians are the sculptors of time. They divide dynasties and mold the contours of periods: antiquity, the Ming, modernity. They calibrate the chronologies that connect and sound the depths of ruptures that separate, from the neolithic revolution to the computer revolution. The shape of time defines the physiognomy of history, its most prominent features and overall coherence, and various schools of history have drawn revealingly different physiognomies: even within the compact province of European history, the German *Barockzeitalter*, the Italian *rinascimento*, the French *âge classique*, and the Anglo-American "early modern period" (not to mention the history of science's "Scientific Revolution") overlap in the time periods covered but diverge sharply in themes and implications. Chronologies, timelines, and tables are to history what atlases are to geography: a map by

[97] Even if the library is located on the Web rather than in a building, the challenges of material durability (e.g., maintaining servers and translating old formats like floppy disks and microfilm into new ones) and archiving are at least as daunting; see the Web Archiving Service, http://webarchives.cdlib.org/ (accessed 30 August 2011). This may be one reason why large, architecturally ambitious libraries are still being built on a grand scale; Markus Eisen, "Zur architektonischen Typologie von Bibliotheken," in *Die Weisheit Baut sich ein Haus: Architektur und Geschichte von Bibliotheken*, ed. Winfried Nerdinger (Munich, 2011), 261–306.

[98] Of course, practices in the humanities also evolve; see Andrew Abbott, "Library Research Infrastructure for Humanistic and Social Scientific Scholarship in the Twentieth Century," in *Social Knowledge in the Making*, ed. Michèle Lamont, Charles Comic, and Neil Gross (Chicago, 2011), 43–88.

which to navigate unmarked territory.[99] To carve up time is the first, essential step to making sense of history—and therefore perpetually controversial.

The same might be said of at least some of the sciences, on a still-grander scale. If the time of history dwarfs the human lifetime, the time of the sciences of earth and sky beggars history. Geologists and evolutionary biologists layer their epochs like the strata of rock and embedded fossils they name: the lower Cretaceous, the upper Cretaceous. Epochs are swallowed up by periods and periods in turn by eras, each at least 150 million years long. Astronomers track the birth and death of stars, indeed of the entire universe—beside which the period of the precession of the equinoxes, a mere twenty-six thousand years, shrinks to a pinpoint. To contemplate these oceans of time stokes both poetic sublimity and scientific explanation: the vertiginous possibilities of Kant's infinity or Darwin's natural selection. Yet even the mind-boggling expanses of geological and astronomical time must be mapped. In the historical sciences, as in history, the precondition for knowledge is a cartography of time.

So it is striking that the practices of the sciences of the archives, whether oriented toward the past or the future, are so indifferent to those continents of time called "periods" or "epochs" that make oceans of time navigable. The early modern naturalists who combed libraries for past observations of plants or volcanoes or seasonal winds and the astronomers at the turn of the twentieth century who laid down an archive for the turn of the thirtieth century largely believed, like Cuvier, in a vague sort of progress in the quality of observation: modern, firsthand, authored observations were generally superior to the ancient, secondhand, anonymous sort; detailed descriptions and above all precise measurements were preferable to nebulousness; the accuracy and reliability of instruments had improved steadily in the past and could be counted upon to continue to do so in the future. But this overall vector of amelioration did not lead them to abandon either libraries or archives in disgust (declaring that past observations are useless) or despair (fearing that future observers would find their observations to be useless), much less to a periodization of the ages of observation. There were no iron, silver, and golden ages; not even ages of good record keeping and bad. There were just data strewn across the flat expanse of time.

As in the case of Cuvier sifting observations of pachyderms since classical antiquity, users of past scientific data developed their own highly refined form of Quellenkritik, poking and prodding past accounts for accuracy and reliability. But in contrast to the historian's practice of that wary art of cross-examining one's sources, there was little awareness of the systematic distortions of anachronism. Historians acquire a period ear, analogous to the period eye of historians of art. Beliefs, turns of phrase, orthography, even punctuation bear the stamp of a time and place, and even tiny anomalies can jar the period ear and inflame suspicions of forgery. For the scientists, in contrast, there were only good observers and bad observers, and both kinds could appear anywhere, in a dusty manuscript centuries old or in the latest journal. This leveling view of history was and remains the precondition for the centrality of the library in the sciences of the archive.

For historians, nothing could be more puzzling, shocking even, than this tone deafness for anachronism (however exquisite the sensibility for other aspects of past data). If the cardinal sin of anthropologists is ethnocentrism, that of historians is

[99] Daniel Rosenberg and Anthony Grafton's *Cartographies of Time: A History of the Timeline* (New York, 2010) offers a remarkable collection of such ways of visualizing the epochs of history.

anachronism—in both cases, the criminally naive assumption that the inhabitants of other times and places are just like one's next-door neighbors, albeit oddly attired and quaintly spoken. But this neighborly assumption was the very basis for collective empiricism: a conception of a community that of necessity transcended space and time. The word *community*, with its cozy, egalitarian associations, is perhaps not le mot juste here and in any case does not appear to have been used systematically in a scientific context much before the late nineteenth century. Scientific utopias, from Bacon's House of Salomon to the Saint-Simonian phalanxes, could be rigidly hierarchical; the division of labor could resemble that of a Victorian factory. What remained constant were the voracious demand for scientific labor and the challenge of organizing it in ways unprecedented except perhaps in organized religion. This may be why utopias recur so frequently in modern science, visions of alternative polities that sprawl over continents and centuries, in the teeth of the realities of local institutions and the human life span. Only in the library and the archive could their time-defying aspirations be realized.