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The Empire of Observation, 1600–1800

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By circa 1600, as the previous essay by Gianna Pomata shows, observation had become an epistemic genre, especially among astronomers and physicians but also among jurists and philologists: an increasing number of book titles proudly announced their contents as "observations," understood as the results of empirical inquiry. Characteristic of the emergent epistemic genre of the *observationes* was, first, an emphasis on singular events, witnessed firsthand (*autopsia*) by a named author (in contrast to the accumulation of anonymous data over centuries described by Cicero and Pliny as typical of *observationes*); second, a deliberate effort to separate observation from conjecture (in contrast to the medieval Scholastic connection of observation with the conjectural sciences, such as astrology); and third, the creation of virtual communities of observers dispersed over time and space, who communicated and pooled their observations in letters and publications (in contrast to passing them down from father to son or teacher to student as rare and precious treasures). By circa 1750, observation had also become an *epistemic category*, that is, an object of reflection that had found its way into philosophical lexica and methodological treatises.[1] Observation had arrived, both as a key learned practice and as a fundamental form of knowledge. As the Genevan naturalist Charles Bonnet wrote in 1757 to his fellow observer, Bern anatomist and botanist Albrecht von Haller: "I have often revolved in my mind the plan of a work that I would have entitled *Essay on the Art of Observing*. I would have collected as in a tableau the most beautiful discoveries that had been made since the birth of philosophy. . . . I would have demonstrated that the spirit of observation is the universal spirit of the arts and sciences."[2]

The consolidation of an epistemic genre primarily linked to astronomy and medicine in the sixteenth century into an epistemic category essential for all the arts and sciences by the early eighteenth century was the result of remarkable innovations in the making, using, and conceptualizing of observation: new instruments like the telescope and microscope; new techniques for coordinating and collating the information produced by far-flung observers ranging from the questionnaire to the synoptic map; new thinking about the relationship between reason and experience—or rather, about new forms of reasoned experience, most prominently observation and experiment. As an epistemic category, "observation" took its place among a throng of other early modern innovations in the realm of disciplined experience.[3] The most important of these was "experiment," whose meaning shifted from the broad and heterogeneous sense of *experimentum* as recipe, trial, or just common experience to a concertedly artificial manipulation, often using special instruments and designed to probe hidden causes. By the early seventeenth century, "observation" and "experiment," seldom coupled in the Middle Ages, as Katharine Park notes in her essay in this volume, had become an inseparable pair, and have defined and redefined each other ever since. In the period from the early seventeenth to the mid-nineteenth century, the relationship between observation and experiment shifted not once, but several times: from rough synonyms, as in the phrase "observations and experiments" that had become current by the early seventeenth century, to complementary and interlocking parts of a single method of inquiry throughout much of the eighteenth and early nineteenth centuries, to distinct procedures opposed as "passive observation" and "active experiment" by the mid-nineteenth century. The relationship between observation and conjecture was also in motion during this period, evolving from deliberate segregation in the late sixteenth and seventeenth centuries to equally deliberate interaction by the latter half of the eighteenth century, when observation became an "art of conjecture."

The emergence of observation as a recognized form of learned experience in early modern Europe did not, however, alter a fundamental aspect of observation that had been prominent since the Middle Ages, if not earlier, and is amply documented in the other essays in part 1 of this volume: observation and observance remained tightly intertwined. Although the kinds of observances required by new contexts and modes of observation did change dramatically, observation remained a way of life, not just a technique. Indeed, so demanding did this way of life become that it threatened to disrupt the observer's other commitments to family, profession, or religion and to substitute epistolary contacts with other observers for local sociability with relatives and peers. The metaphorical "family" developed among observers in the context of the emergent epistemic genre of the *observationes* in the late sixteenth century threatened by the mid-eighteenth century to displace the observer's literal family—as when French naturalist Louis Duhamel du Monceau depleted not only his own fortune but that of his nephews on scientific investigations.[4] By the late seventeenth century, the dedicated scientific observer who lavished time and money on eccentric pursuits was a sufficiently distinctive persona in sophisticated cultural capitals like London or Paris to be ridiculed by satirists and lambasted by moralists.[5] In the course of the seventeenth and eighteenth centuries, scientific observation was theorized and practiced, disseminated and celebrated with missionary-like enthusiasm, as its adherents opened up a veritable empire of observation.

Observation and Experiment

How did the term "observation" broaden its meaning and significance to become an essential aspect of both the theory and practice of natural knowledge by the late seventeenth century? The obverse of this question is how the widely diffused, all-purpose word "experiment" during the same period narrowed its scope to denote a carefully designed human intervention into the ordinary course of nature. Although Francis Bacon's own vocabulary did not fix the fluid meanings of *observatio*, *experimentum*, and *experientia*,[6] avowed Baconians played a key role in the rise of the terminology of observation and experiment in mid-seventeenth-century scientific circles. The academies (and some private groups, such as the circle around Samuel Hartlib in London[7]) founded in northern Europe during the middle decades of the seventeenth century, in imitation of earlier Italian academies like the Roman Accademia dei Lincei (established 1603), seem to have provided the crucible that fused the Baconian program for a natural philosophy grounded in an enlarged and improved natural history with the earlier medical project of collecting *observationes*.

The earliest of these transalpine academies, the Academia Naturae Curiosorum (Academy of Those Curious about Nature; later known as the Leopoldina) established in the imperial city of Schweinfurt in 1652 by a handful of German physicians, was perhaps the clearest example of this fusion.[8] In the late 1660s the officers of the Academia Naturae Curiosorum issued an invitation to the "learned all over Europe" to submit their "observations and experiments" on anything "rare and hidden in physic or medicine" to be collected and published with the names of the contributors in an annual volume, variously known as the *Ephemerides* or the *Miscellanea curiosa*, with the academy's imprimatur.[9] The early volumes reported on the activities of sister academies in Florence, London, and Paris (which were sent copies), and Bacon's House of Salomon, an imagined institution for lavishly funded scientific research, was explicitly held up as a model.

Although the Academia Naturae Curiosorum's official focus was on medicine, it self-consciously emulated the Royal Society of London (established 1660) and the Paris Académie Royale des Sciences (established 1666) in the form and scope of its publications: short firsthand reports submitted by—as the preface to the 1669 volume of the *Philosophical Transactions* put it—"all Ingenious Men, and such as consider the importance of Cementing Philosophical Spirits, and of assembling together Ingenuities, Observations, Experiments and Inventions, scattered up and down the World;. . . ."[10] As the wording of this invitation suggests, the vocabulary of the *Philosophical Transactions* was not as influenced by the medical model of *observationes* as that of the *Miscellanea curiosa.* In a 1665 letter to Breslau physician and Academia Naturae Curiosorum member Philip Jacob Sachs von Lowenhaimb, Henry Oldenburg, editor of the *Philosophical Transactions* and secretary to the Royal Society, emphasized the Society's more sweeping ambitions: "I understand that your Academy is composed of medical men only . . . But our Society, aiming at other things, is composed of men of all ranks who are distinguished in letters or by their experience [*tum literis tum experientia*], and enrolls mathematicians, physicists, mechanicians, physicians, astronomers, opticians, etc. It is about to reconstruct philosophy, not as it pertains to medicine alone, but as it concerns all that pertains to the usefulness and convenience of human life . . . to this end it is busy with nothing so much as building up a store and treasury of observations and experiments [*Observationum et Experimentorum*]."[11]

The titles of the articles published by the *Philosophical Transactions* in its first decades reflect this broader constituency and less-specialized vocabulary: many but by no means all titles relating some event or object investigated firsthand contained the word "observation" (and variants such as "observables"); of these, only some followed the medical format of numbered items. Yet these articles nonetheless bear witness to a meaning of the term "observation" that had at once expanded and sharpened: "observations" on everything from may dew to silkworms joined examples in astronomy and medicine, but the sense of "observation" in the late seventeenth-century context was now explicitly linked to *autopsia*, as opposed to remarks upon someone else's observations or hypotheses, which were designated as "considerations" or "animadversions."[12]

A parallel consolidation of term and meaning appears to have taken place in the annals of the Paris Académie Royale des Sciences in the 1660s and

1670s. Like the Royal Society of London, the Paris Académie aimed to be more comprehensive in its membership and inquiries than the medical Academia Naturae Curiosorum. But as in the case of the Royal Society, medical men were prominently represented among its members and correspondents.[13] Several of the works, including books and especially pamphlets, published under its auspices during this period, are presented as "observations."[14] After the *Histoire et mémoires de l'Académie royale des sciences* began regular publication from 1699 on, "diverse observations," under which individual short observations were presented in numbered lists with the names of the observers, became a regular feature of the *Histoire* section.[15] The term was used often in the manuscript minutes of the Académie from the pre-1699 period, almost always where astronomical or meteorological information was presented, frequently for anatomical reports and occasionally for accounts of botanical, chemical, and physical phenomena.[16] In all cases, *observation* denoted a firsthand report in which the time and place were scrupulously noted. Even those observations that were not presented in a numbered list, after the fashion of the medical *observationes*, were of well-circumscribed objects or events, including those observations that were routinely repeated (e.g., daily thermometer and barometer readings). By the turn of the eighteenth century, "observation" had become an essential practice in almost all of the sciences, not just astronomy, meteorology, and medicine—and the complement and supplement of "experiment."

In Latin and in the vernacular, the terms *experientia/experimentum* appear to have undergone an analogous focusing in the latter half of the seventeenth century, which fixed their meanings well into the eighteenth century. In the medieval period through the early seventeenth century, these words were often used interchangeably, covered a broad range of empirical procedures ranging from experience in general to the artisanal trial or medical recipe, and occurred with considerably greater frequency than *observatio* and its variants,[17] at least in texts about natural knowledge. Probably the most celebrated seventeenth-century use of the word *experimentum*, Bacon's *experimentum crucis* that decided between rival hypotheses, was introduced in the context of a sifting and comparison of observations.[18] English natural philosopher Robert Hooke, for example, perpetuated this sense when in 1679 he described the observation of stellar parallax as the *experimentum crucis* with which to test the Copernican hypothesis.[19]

Yet in the *Novum organum* (1620) and especially in his histories of various natural phenomena, Bacon occasionally and consequentially became more specific in his usage: *experimentum* referred to a deliberate manipulation that would shed light on causes inaccessible to the unaided senses and intellect, not just produce an effect. In addition to exhorting natural philosophers to pay greater heed to "all the experiments [*experimenta*] of the mechanical arts and all the operative parts of the liberal [arts],"[20] he proposed several specific "experiments" of his own, for example, regarding the rarefaction and compression of air, described in considerable detail: "We took a glass egg, with a small hole at one end. . . ."[21] These were "artificial experiments," as opposed to those provided by the ordinary course of nature, and imitated nature's "sports and wantonings": for example, gunpowder was an "artificial experiment" that explained the cause of lightning.[22] In explicit contrast to the trials of the workshop or the marvels of nature, these Baconian operations on nature were to be first and foremost experiments of "light" rather than of "fruit": only once nature had been understood could it be commanded.[23]

What Bacon called "artificial experiments" became the model for "experiment" tout court by circa 1660. The language of artifice, intervention, manipulation, demonstration (both in the sense of proof and spectacle), and causal inquiry increasingly defined the *experimentum* (known, however, as *expérience* in French and *esperienza* in Italian, a lingering echo of the medieval twins *experientia*/*experimentum*).[24] By the late seventeenth century, the nice-minded were drawing distinctions between *experimenta* and *observationes* on the basis of whether one intervened in the course of nature to produce an effect or studied effects as they occurred in the course of nature: according to German natural philosopher Gottfried Wilhelm Leibniz, "there are certain experiments that would be better called observations, in which one considers rather than produces the work."[25] Other distinctions emphasized that observation examined nature as presented to the senses (with or without the aid of instruments), while experiment revealed hidden effects or causes.[26] By the mid-eighteenth century, usage in English, French, and German had crystallized around some form of this distinction.

The terms nonetheless remained intertwined, if distinct, throughout the eighteenth century, as countless titles of the form "Observations and Experiments" testify. In 1756, French mathematician and *philosophe* Jean Le Rond d'Alembert characterized the interaction between observation and experiment as a never-ending loop: "Observation, by the curiosity it inspires and the gaps that it leaves, leads to experiment; experiment returns to observation by the same curiosity that seeks to fill and close the gaps still more; thus one can regard experiment and observation as in some fashion the consequence and complement of one another."[27] The English natural philosopher Joseph Priestley, author of one of the most celebrated eighteenth-century collections of "observations and experiments," similarly emphasized how experiments ramified into observations, which in turn led to new experiments, yielding further observations, stoked by endless curiosity.[28] Although various eighteenth-century accounts valorized either one of the terms at the expense of the other, almost all viewed the two forms of inquiry as working in tandem.[29]

Coordinated Observation

Since ancient times, observation had been understood as collective, as the slow accumulation of anonymous observations over generations, centuries, even millennia. But when observation was reconceived in early modern Europe as the province of doctors, scholars, naturalists, and other literate elites, the nature of that collectivity changed radically: authored observations were systematically made and recorded, exchanged in letters, published in books, and gathered by individuals, governments, mercantile corporations, and scientific societies. Some of these new collectives of observers were informal, albeit crucial to the development of sciences like botany: adopting the epistolary habits of Renaissance humanists, learned naturalists such as Conrad Gessner in sixteenth-century Zurich or Carolus Clusius in Leiden exchanged observations (both in word and image) just as they exchanged specimens and seeds of plants.[30] By the late seventeenth century such letters were sent to and solicited by the editors of learned journals such as the *Philosophical Transactions* and the *Miscellanea curiosa*, who transformed them into the first scientific articles simply by deleting the opening greetings and concluding compliments.[31] But such publications did not replace the personal correspondence of savants, which remained an important means of collectivizing observation throughout the eighteenth century and could rival the networks of major academies in their number of correspondents and geographic reach, as in the case of the Swedish naturalist Carl Linnaeus.[32]

Other early modern observer collectives were more formal and centralized, depending on paid labor and hierarchies of command rather than voluntary contributions from self-declared citizens of the Republic of Letters. The Holy See and the Spanish Council of the Indies issued voluminous questionnaires to solicit the observations of missionaries and colonial administrators, respectively, in foreign lands; trading companies such as the Dutch East India Company instructed their functionaries to file detailed reports on their travels.[33]

Although formal and informal observer collectives were differently organized, the boundary between them was often blurred: the Royal Society resorted to questionnaires and eagerly interrogated merchants about the natural history of faraway lands; well-traveled Jesuits published accounts of their missions abroad that were reviewed in learned journals and plundered for observations; botany, imperialism, and commerce were braided together in the global trade in new pharmaceuticals; humanist travel for personal edification shaded imperceptibly into official travel in the service of the crown, deploying similar observational grids. Bacon's imagined "Merchants of Light," described in his utopian fragment *The New Atlantis* (1627), were supposed to sail the world's seas as spies in order to supply the "Interpreters of Nature" at the pinnacle of the House of Salomon with "knowledge of the affairs and state of those countries to which they were designed, and especially of the sciences, arts, manufactures, and inventions of all the world"[34]—a neat and prescient conflation of the diplomatic, mercantile, and scientific models of early modern collective observation.

The explosion of collective observational activity created a new challenge of integration: how to coordinate observers, standardize instruments and regimens, and correlate results? When observations had been rare and costly to make, as in medieval astronomy, or left uncollected and untransmitted in doctors' personal notes or individual diaries, as Katharine Park describes in her essay in this volume, or confined to local phenomena such as the weather and farming conditions, integration had posed few problems. But as observations multiplied, diversified, and diffused and the ambitions of observational programs like those of imperial powers or transcontinental trading companies swelled, ways of collecting and sorting out the results became urgently needed.

Compendia were a typically humanist response to the problem: adapting the techniques of commonplace books, erudite compilers with well-stocked libraries combed the work of ancient and modern authors to assemble thick volumes of selected, indexed observations on all manner of topics. This was the bookish method plied by medical authors such as Johann Schenck and also by naturalists such as Gessner in his *Historiae animalium* (1551–60)[35] or Bacon in his unfinished *Sylva sylvarum* (1627).[36] The collective empiricism encouraged by seventeenth-century periodicals like the *Miscellanea curiosa* and the *Philosophical Transactions* modified the humanist compendium model to solicit new observations made by named contemporaries, substituting eyewitness testimony for bookish scholarship. But the use of the library to construct series of observations, sometimes reaching back to antiquity, continued to be an important observational technique.

The limitations of compendia soon became evident, especially as methods of observation were refined and standards raised: from the standpoint of naturalists increasingly skeptical about the reliability of classical authors like Pliny,[37] observations attributed to authors of varying credibility or to no authors at all and made under diverse or unspecified conditions heaped up helter-skelter seemed unlikely to supply the solid foundation for a reformed natural philosophy.[38] Even compendia of observations freshly made by trustworthy reporters were too heterogeneous to be summed into generalizations or sifted for regularities: despite the efforts of some editors to append "scholia" or "histories" to individual observations in order to bring out their connections to other observations and larger significance, in the spirit of Bacon's "major observations,"[39] the contents of mid-seventeenth-century scientific journals remained stubbornly miscellaneous—and therefore a disappointment to those who, like Oldenburg, hoped to use them to mobilize the Republic of Letters for a program of coordinated, global observation.

Several attempts were made to counter the dispersion of observations, both before and after the fact. Since the mid-sixteenth century (and well before, in the case of Venetian ambassadors),[40] states and mercantile enterprises trained their representatives in foreign parts to observe and report according to standardized schemes: questionnaires, synoptic tables, Ramist branching charts. Observational grids ranged from curt instructions like Sir William Petty's unpublished lists ("Get the best map of the country." "The value of fruites in winter and somer.") to voluminous lists of questions like the two hundred published by the diplomat and humanist Heinrich Rantzau, which covered everything from the exact point of sunset to musical instruments to the salaries of local clergy.[41] Starting with the Swiss encyclopedist Theodor Zwinger's *Methodus apodemica* (1577), manuals aimed at scholars, young gentlemen, ambassadors, missionaries, merchants, colonial administrators, and other travelers instructed readers on what to look at and how in foreign climes.[42] By the early seventeenth century, observation had become a named practice that travelers were exhorted to cultivate, as in the revised 1630 English translation of Giovanni Botero's *Relationi universali* (1597–98), which added a section "Of Observation."[43]

The questionnaire format was adopted by the Royal Society, which eagerly sought information from travelers in order to compile its Baconian natural histories, despite the problems of verifying marvelous tales from distant lands.[44] Robert Boyle recommended the preparation of a compendium of travel reports to Oldenburg in 1666 and in the first volume of the *Philosophical Transactions* published a natural history questionnaire for any "Countrey, Great or Small."[45] In his fragmentary "The General History of the Air," Boyle had also called upon everyone "who hath leisure, opportunity, and time" to keep a diary of "his own observations of the change and alteration of the air from day to day," emphasizing the utility of such mundane "histories."[46] Instead of the questionnaire format, tables or "schemes" like that proposed by Hooke in 1663 were intended to make the weather observations sent in by correspondents all over Europe commensurable and comparable with one another.[47] In 1723, James Jurin, in his capacity as secretary to the Royal Society of London, went one step further in his Latin invitation to potential observers, offering to provide instruments and giving detailed instructions as to when, where, and how to deploy them.[48]

In such dragnet calls for observations to be sent in from far and wide, the scientific societies of the late seventeenth and early eighteenth centuries shifted the emphasis from observation as individual self-improvement, a prominent theme in earlier humanist travel guides, to observation as a collective, coordinated effort in the service of public utility. As English philosopher John Locke wrote when he published his own weather observations: "I have often thought that if such a Register as this, or one that were better contriv'd, with the help of some Instruments that for exactness might be added, were kept in every County in England, and so constantly published, many things relating to the Air, Winds, Health, Fruitfulness, & c. might by a sagacious man be collected from them, and several Rules and Observations concerning the extent of Winds and Rains, & c. be in time establish'd, to the great advantage of Mankind."[49]

Questionnaires, schemata, and instruments supplied by a central authority—princely, ecclesiastical, or scientific—aimed to press observations into a uniform grid. But these preliminary standardizing measures (which also included supervised drawings, as Daniela Bleichmar describes in her essay in this volume), even when followed scrupulously by roaming merchants, officials, missionaries, and dispersed savants, did not suffice for the smooth integration of the observations that accumulated. There were too many observations, too variously taken, and too obscurely correlated with other observations. As J. Andrew Mendelsohn documents in his essay in this volume, the predicament for the networks of seventeenth- and eighteenth-century weather watchers was dramatic: repeated efforts to sift the piles of reports in search of reliable correlations between rainfall and barometric data, wind and rain, temperature and illness, and any number of other hypotheses failed to yield the desired "Rules and Observations" of the weather.[50] Early modern statesmen were confronted with similar challenges: how to collate the stacks of reports and questionnaires sent in by ambassadors and local officials? As a late-seventeenth-century response to the problem of integrating observations by far-flung correspondents, a vogue for "synopses," "calendars," "registers," "tables," and other visual digests edged out the indices and *loci communes* devised by humanist compilers a century earlier. Tables that correlated two or more observed variables, used since ancient times in astronomy, spread in the late seventeenth and early eighteenth century to meteorology, experimental natural philosophy, and natural history.[51] In an unpublished memo probably intended for one of the rulers he served, Leibniz proposed a "State Table" that would digest all the oral and written accounts of well-traveled informants into a compact summary that the prince could "look over in a moment" and thereby grasp "the connections of things."[52]

Leibniz compared his handy table to "maps of land and sea," and one of the most successful efforts to integrate the results of collective observation was a world map showing prevailing wind patterns prepared by the English astronomer and natural philosopher Edmond Halley in 1686 (fig. 3.1). On the basis of published accounts, conversations with mariners, and his own seafaring observations, Halley discerned a few general "rules" (albeit with exceptions) in the direction of the trade winds above and below the equator and the seasons of regional storms such as Caribbean hurricanes and Indian monsoons. Like Leibniz's table, Halley's map or "Scheme" showed "at one view all the various Tracts and Courses of these Winds."[53] Although Halley's synoptic map and general explanation of global wind patterns was an all-too-rare triumph of collective observation in the seventeenth and eighteenth centuries, it can stand as an emblem for the ambitions of such programs. Inspired by Bacon's project for a "history of the winds," Halley's synthesis drew, as Bacon had hoped, on "a Multitude of Observers, to bring together the experience requisite to compose a perfect and compleat History of these Winds," including not only natural philosophers but navigators and travelers. But in contrast to Bacon's vision of a centralized, state-financed, hierarchically organized corps of observers subordinated to the "Interpreters of Nature" in Salomon's House, Halley's informants were volunteers, and he himself was a seafaring observer, a "Merchant of Light" as well as an "Interpreter of Nature." The merging of these two roles of roaming observer and discoverer of "greater observations, axioms, and aphorisms"[54] was to prove consequential for the practices of learned observation: the eye of the body and the eye of the mind had to be taught to work in harmony.

Observational Practices

By the late seventeenth century, special procedures, carried out by specially qualified people under special circumstances, distinguish the scientific observation from the all-purpose remark. At the very least, scientific observers were expected to exercise unusual care, sometimes as a group cross-checking its individual members. In his preface to the third year of the *Philosophical Transactions*, Oldenburg expressed the hope that "our Ingenious Correspondents have examin'd all circumstances of their communicated Relations,

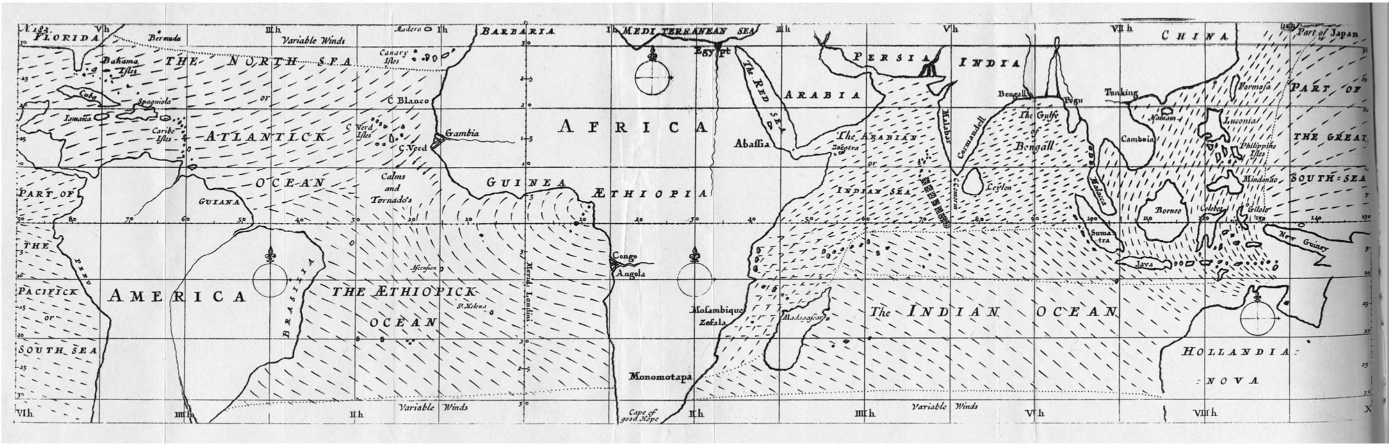

FIGURE 3.1. Map of the world winds. Edmond Halley, "An Historical Account of the Trade Winds, and Monsoons, observable in the Seas between and near the Tropicks, with an attempt to assign the Phisical cause of said Winds," *Philosophical Transactions of the Royal Society of London* 16 (1686–92): 153–68, foldout between pages 49 and 51.

with all the care and diligence necessary to be used in such Collections."[55] These sentiments were echoed in the Paris Académie's *Histoire naturelle des animaux*, which purportedly contained "no facts that have not been verified by the whole Company, composed of people who have eyes for seeing these sorts of things, in contrast to the majority of the rest of the world. . . ."[56] Scientific observers in the seventeenth and eighteenth centuries self-consciously developed novel practices that schooled perception, attention, judgment, and memory. Tools such as the notebook and the magnifying glass were enlisted in these practices. As observation became repetitive as well as collective, the challenge of synthesizing the sequence of notes made by an individual complemented that of integrating the ensemble of reports produced by a community.

REPETITION

Although sustained observation over generations had since ancient times been considered characteristic of the ways in which astronomers, farmers, sailors, and shepherds discovered regularities about the stars and the weather, regimens of repetitive observation of the same object were rare before the early modern period. The example of astronomy, as the most ancient of the observational sciences (and the one longest and most consistently associated with the term), is instructive concerning how a cumulative observational tradition became a repetitive one.

When the French astronomer Jean Picard journeyed to the Danish island of Hven in 1671 to conduct astronomical observations from the ruins of Danish astronomer Tycho Brahe's castle Uraniborg and bring back Tycho's manuscript observations to Paris, he bore witness to the strong sense of continuity that bound even the most boldly innovative early modern astronomers to their predecessors.[57] Part of the care with which late sixteenth- and seventeenth-century astronomers preserved and transposed past observations stemmed from the superhuman temporal scale along which some celestial events, such as the precession of the equinox, unfolded. Only observations carried out over centuries, and in some cases millennia, could discern and specify cycles with long periods or subtle correlations. But part of their solicitude also derived from a desire to test—not just add to—and improve upon past observations, a process that paradoxically led them first to vaunt their own advances and later to cultivate an ever more scrupulous awareness of possible sources of error. Pride in progress as well as fear of error were both tied to what was, at least in the Latin West,[58] a new practice in astronomical observation, with parallels in other early modern observational sciences: the systematic repetition of the same observation night after night, over years and decades.

The consequences of this new practice of sustained and repetitive observation (rather than at special points like quadrature or conjunction) are thrown into relief by a comparison of Tycho's methods of the 1570s and 1580s with those employed a century later. Although Tycho made his reputation with the observation of singular events such as the nova of 1572, analogous to the contemporary medical *observationes* of unusual cases, once established at his purpose-built observatory Uraniborg in the late 1570s, he began a program of sustained observation of the sun, moon, planets, and fixed stars on every clear night for over twenty-one years. His account of solar observations made clear that he was well aware of the novelty of this program: "First of all we determined the course of the sun by very careful observations during several years. We not only investigated with great care its entrance into the equinoctial points, but we also considered the position lying in between these and the solstitial points, particularly in the northern semicircle of the ecliptic since the sun there is not affected by refraction at noon. Observations were made in both cases and repeatedly confirmed, and from these I calculated mathematically both the apogee and the eccentricity corresponding to these times."[59]

Tycho's arduous, costly, decades-long regimen of observation, involving many new instruments of his own invention and of unprecedented size and accuracy, was intended to make future observations superfluous, at least in those areas to which Tycho had devoted the most time and effort. At least his mature observations, Tycho thought, were "completely valid and absolutely certain"[60] and would never need to be repeated. Yet by the 1670s, leading astronomers considered Tycho's observations insufficiently exact. As Astronomer Royal John Flamsteed wrote to Samuel Pepys in 1697 apropos of Tycho's cherished fixed-star observations, "though what he did, far excelled all that was done before him; yet it was much Short of the exactness requisite in this Business."[61] One reason why Flamsteed could pronounce Tycho's observations outdated was the introduction of telescopic sights and the micrometer, both invented circa 1640 but not put into systematic use until the 1660s. Although the telescope had been responsible for some spectacular discoveries in the hands of Galileo and others during the seventeenth century,[62] it by no means displaced sextants and quadrants; telescopic sights arguably contributed more to astronomical observations during this period than the telescope itself did, refining angular resolution to 15 seconds of arc by 1700.[63]

It was not only improvements in instrumentation that persuaded late seventeenth- and eighteenth-century astronomers that their observations were an advance on Tycho's, just as Tycho had vaunted the quality of his observations over those of all previous astronomers. The very practice of sustained, continuous observation that Tycho had institutionalized sharpened the astronomers' awareness of the possibility, perhaps the inevitability, of error. The more observations are made, the more likely it is that they will diverge from one another. Tycho's Uraniborg had been in operation for only about twenty years, but this was long enough to notice a scatter of data and to redouble vigilance to counteract the possible effects of atmospheric refraction, the sagging and stretching of heavy instruments under their own weight, jumpy clocks, and a myriad of other disturbances. But the problem did not go away, no matter how many precautions were taken. With the establishment of observatories like those in Greenwich and Paris in the late seventeenth century,[64] observations stacked up over decades and even centuries. At the Paris Observatory, Picard worried about whether the smoked glass through which the sun was observed might distort the solar diameter or whether the effects of refraction were greater in the winter than in the summer—and many other sources of minute errors.[65] By the first half of the eighteenth century, a heated debate had begun among astronomers about what to do with discordant observations. In astronomy, these were issues that were moralized, mathematized, and ultimately psychologized.[66] Despite these problems, however, by the mid-eighteenth century, all scientific observation was ideally repeated, continuous observation, in studied contrast to the singular or rare phenomena that had dominated medical and scientific collections of *observationes* a century or so earlier.

NOTE TAKING

Some form of note taking has probably since ancient times been part of taking note, of remarking, describing, and remembering—in short, of observing. But note taking itself has a history, one that was consequential for the practices of observing in the early modern period.[67] Two notebooks, one from the late seventeenth century and the other from the late eighteenth century, illustrate some of these changes.

The first was kept by Locke, from September 1666 to April 1703, and entitled "Adversaria physica," or "memoranda on physic."[68] It is a large-ish (approximately 8″ × 12″) calf-bound volume, written in ink, and continuously paginated. The entries, written in Latin, English, and French, relate mostly to medical but also to some natural philosophical matters, mingling excerpts from reading (with references), recipes for medications (e.g., Lady Chichley's eye ointment), practical tips (e.g., where to get the best French olive oil), and some of Locke's own observations, initialed "JL." At the back of the volume is a weather diary, presenting daily thermometer, barometer, hygrometer, and wind observations for a period of almost thirty-seven years (fig. 3.2) These are the only dated entries; insofar as there is another order, it is spasmodically alphabetical, with an elaborate but incomplete index at the front and back of the volume; most of the entries are flagged with a marginal keyword (e.g., "Reason," "Fulmen," "Palpitatio cordis").[69]

Locke's mélange of reading notes and observations was not exceptional in seventeenth-century commonplace books.[70] Culling facts from experience bore some resemblance to culling information and insight from books, and the commonplace books that held the latter were similar in form and aims to the lists and tables that held the former. Among the personnel in Bacon's House of Salomon there were not only "Mystery-men" who collected experiments in the mechanical arts; there were also "Depredators" who collected experiments from books.[71] The keeping of commonplace books of quotations and moral adages culled from the reading of classical authors was a pillar of early modern education in rhetoric.[72] The engrained humanist habits of excerpting, ordering, and recombining the entries of commonplace books offer a suggestive parallel for at least the recording of facts about nature, as in Locke's case. Bacon himself is alleged to have preferred the keeping of commonplace books to other forms of note taking on reading, "because they have in them a kind of Observacion."[73]

A notebook from about a century later offers a study in contrasts. On 10 July 1774 the Genevan naturalist Horace-Bénédict de Saussure began a little yellow notebook (approximately 5″ × 7″), which he labeled "Voyage autour du Mont Blanc en 1774, 10e Juil. Brouillard en crayon No.1. Extraits de l'Agenda." Each page was headed with the day of the week and the date, followed by a lettered (a, b, c, etc.) sequence of short observations, beside each of which was noted the time, often to the minute. Although Saussure recorded a terse "agenda" of the main topics to be covered by the observations on the notebook's flyleaf, he strayed from "primitive and secondary mountains" when something else caught his eye along the way: a ruined château, the strata of slate that struck him as displaced from their original position, the nickname of his local guide, barometer and thermometer readings, a terrifyingly steep mountain pass traversed in the snow in mid-July. The timed entries and the execrable handwriting suggest that the entries were made in real time, bouncing along on a bumpy mountain road. Some entries are exceptionally in ink and in a far more legible hand: "Sunday, 17 July. (a) This morning was set aside for rest or at least some observations at Cormayer. However, I was not

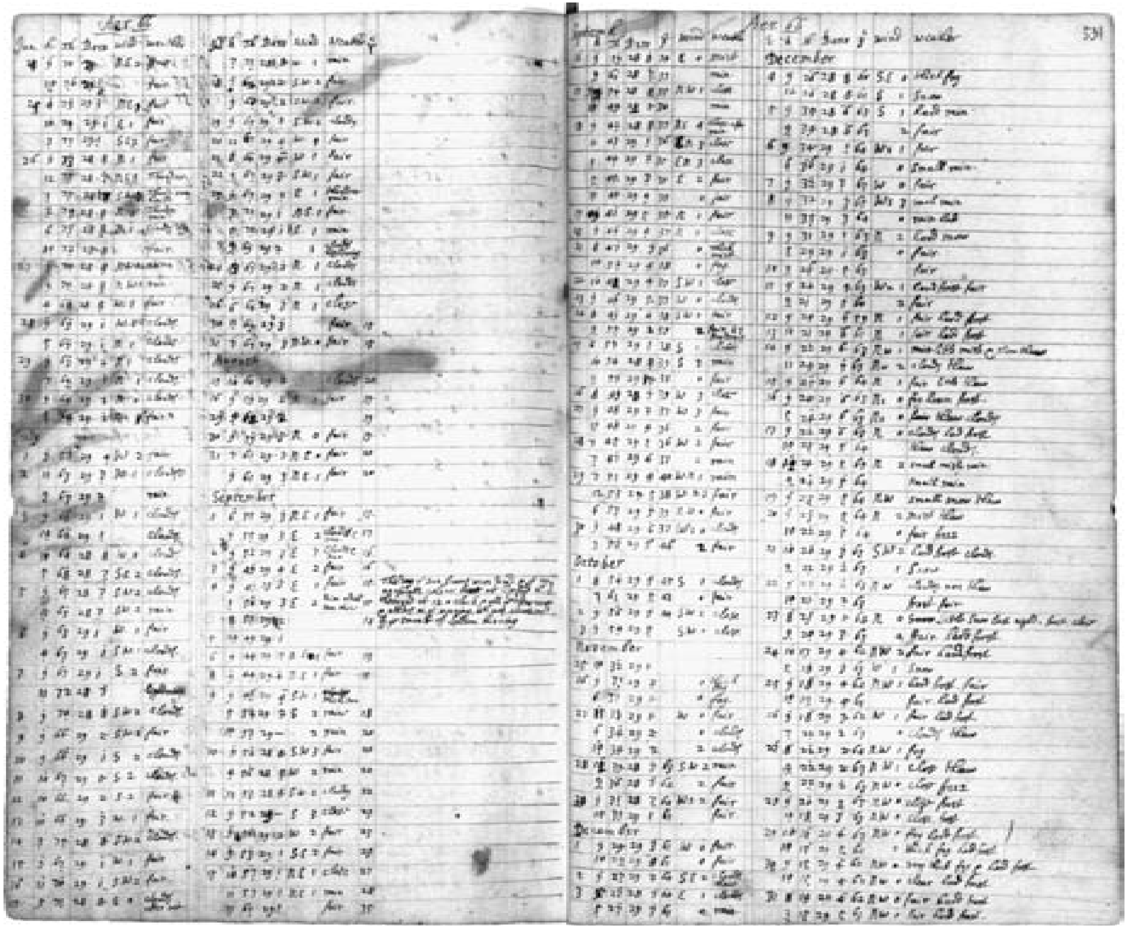

FIGURE 3.2. Weather table. John Locke, "Adversaria physica." Bodleian Library, University of Oxford, Shelfmark MS Locke d.9.

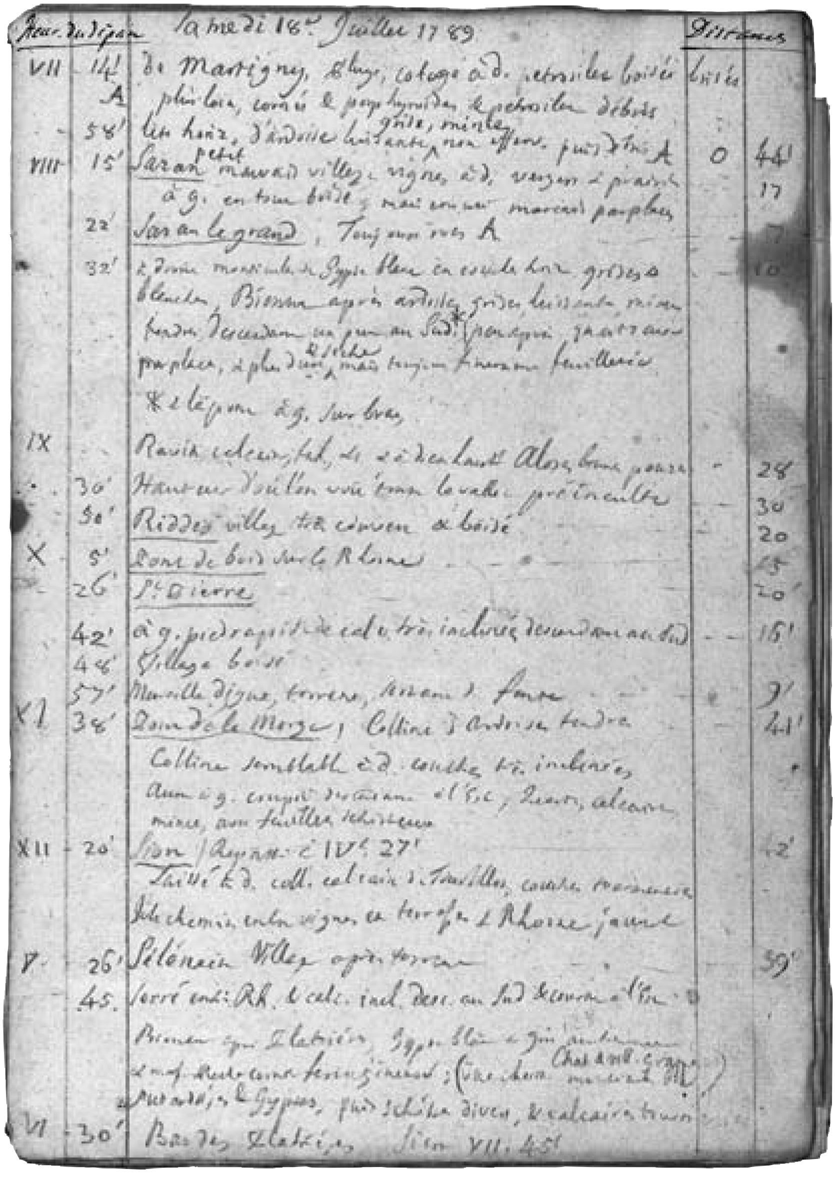

FIGURE 3.3. Pencil and ink observation notebook entries. Horace-Bénédict de Saussure, "Voyage autour du Mont Blanc en 1774, 10e. Juil. Brouillard en crayon No.1. Extraits de l'Agenda," Bibliothèque de Genève, Archives de Saussure 14/1.

at all tired from yesterday, however arduous it had been. (b) I made a trial of several rocks gathered yesterday with eau fort . . ." (fig. 3.3).[74]

This is a typical observation notebook from the latter half of the eighteenth century: pocket format, dated entries further broken down into subentries by a sequence of letters or numbers, real-time entries in pencil and retrospective entries in ink, descriptive observations interspersed with reflections, conjectures, and personal details. There are no thematic indices or reading notes. The model is the journal, more specifically, the travel journal kept en route rather than the commonplace book filled by the desk-bound scholar: Saussure's cardboard-bound notebook was small and light enough to be carried along everywhere; when Locke traveled to the Continent, he left the bulky "Adversaria physica" at home. Above all, the axis of organization has shifted from the topical to the temporal. Locke's notes were assembled with an eye to collation by subject matter; his commonplace book recycled material from old books into the stuff of new books and was itself a proper book, hefty and leather-bound; the entries (with the exception of the weather tables) are as timeless as the pages of a book. Saussure's record is in contrast driven by the calendar and his pocket watch. Time was almost always the vertical dimension of eighteenth-century tables of observation, whether the object of observation was lunar perturbations, the temperature, the incidence of smallpox, or the reproduction of aphids.

PAYING ATTENTION

For Enlightenment naturalists like Saussure and his uncle Bonnet, observing was first and foremost an exercise of attention. As Swiss Protestant minister and naturalist Jean Senebier wrote in his influential 1775 treatise *L'art d'observer*, "[a]ttention alone renders the observer master of the subjects he studies, in uniting all the forces of his soul, in making him carefully discard all that could distract him, and in regarding the object as the only one that exists for it [i.e., attention] at that moment." The peculiar economy of attention cultivated by the Enlightenment naturalists was pointillist, magnifying, and therefore deliberately repetitive. Visually and intellectually, the observer pulverized the object into a mosaic of details, focusing first on one, then another. Senebier directed the fledgling observer to compensate for the "feebleness of his soul and senses in fragmenting [*morcelant*] the subject of his observations and in studying each of its parts separately." Only the narrowness of focus could sufficiently concentrate attention to the level of intensity required for exact observations.

So pencil-thin and intense was the beam of attention that it could hardly be sustained over long periods. Hence the observer must return over and over again to the same object, picking out different details, different aspects each time, and multiply confirming what had already been observed.[75] Still better was the repetition of observations by several observers, not because the veracity of the initial observations was in doubt, but rather to widen the panorama of different perspectives on the same object. In this spirit, Bonnet urged Italian naturalist Lazzaro Spallanzani to repeat the observations of others, including his own: "Nature is so varied that we can hardly vary our attempts too much."[76] The use of microscopes and, especially, the more portable and versatile magnifying glass also tended literally to focus and circumscribe the observer's attention.[77]

SYNTHESIS AND DESCRIPTION

The result of these practices was an avalanche of descriptive detail, both visual and, especially, verbal. It was a byword among the naturalists that it was by the detail with which observations were reported that one could separate the novice from the old hand, the artisan from the savant, the bumbler from the "genius of observation."[78] The most ingenious efforts of observers were directed toward the discernment of the most fleeting details, the finest nuances. Saussure invented an instrument called the cyanometer to measure the shades of blue of the sky, ranging over fifty-three graduations, from milky white to midnight blue.[79]

No study of natural particulars could afford to become permanently mired in particulars. Bacon had feared naturalists might drown in them; Enlightenment observers gladly wallowed in them—but no one deemed them an end in themselves. The practices of taking notes and paying attention as they were cultivated during the mid- and late-eighteenth century tended to fragment the object of inquiry: numbered, dated notebook entries chopped up time into slices; narrowly focused attention dissolved wholes into tiny parts. Whereas collective observation posed the problem of the coordination of many individuals, the challenge of the practices of synthesis confronted the individual observer: how to glue all these fragments back together again into a coherent mosaic—but not in order to reconstitute the actual object of observation. Instead, the result of the synthesis was a general object—variously described by Enlightenment astronomers, anatomists, and naturalists as an archetype, an ideal, an average, or a pure phenomenon—that was more regular, more stable, more universal, more *real* than any actually existing object.[80]

Although observers were sometimes struck by singular phenomena such as an aurora borealis or a monstrous birth, by the mid-eighteenth century they attempted whenever possible to situate individual objects and events in a series. This practice had its antecedents in the longstanding astronomical practice, common since the late sixteenth century, of creating long baselines of multiple observations of the same star or planet. In other sciences of the eye, observers repeated observations of the same or similar objects in order to establish a series. Linnaeus prided himself upon having examined thousands of plant specimens, many supplied by former students dispatched to distant lands.[81] Johann Wolfgang Goethe, reflecting in 1798 on his researches in morphology and optics, described the quest for the "pure phenomenon," which can be discerned only in a sequence of observations, never in an isolated instance.[82] If such a sequence was not readily available to direct observation because of the rarity of the phenomenon, it was compiled from past records: French astronomer Louis Godin began his report to the Académie Royale des Sciences on the October 1726 aurora with a compilation of all previous such sightings, starting with Flavius Josephus in Roman times and concluding with a summary of the features common to all such cases.[83] Ideally, not only the naturalists but also their artists were supposed to be familiar with a broad range of exemplars, so that images as well as descriptions would be the distillation of not one but many individuals carefully observed.[84]

The process of how particulars were forged into generalities is most graphically displayed in the observation notebooks. Under the rubrics of "Reflections," "Results," or "Remarks" (or—in the case of Saussure—simply the shift from pencil scribblings to inky fairhand) were recorded the digestion of first impressions into second (and sometimes third) impressions. These were observations upon observations, the refinement and distillation of raw materials into what Bacon had called "vintages"—or, in his histories, "major observations."[85] Here the older Renaissance practices of humanist note taking were preserved in spirit if not in substance: what sixteenth-century scholars had done for the writings of Cicero and Livy, eighteenth-century naturalists did for oysters and aphids. A first round of observations selected the noteworthy; a second round winnowed these further by comparisons and cross-correlations, seeking patterns and regularities; a third synthesized the features now understood to be the most significant or essential into the general observation.

Observation as a Way of Life

"Never has so much been observed, as in our century."[86] By the mid-eighteenth century, observation was practiced, theorized, and celebrated in almost all sciences. But because observation and observance remained conjoined, the very success of observation, demanding ever more time and dedication from its practitioners, made it controversial as a way of life, an observance too absorbing to be easily compatible with other social, professional, and religious commitments.

Although it never ceased to be arduous, and was recognized to be dangerous at times, early modern scientific observation was seldom described as work (except perhaps by the astronomers: Flamsteed at least complained that it was "labour harder than *thrashing*"[87]). On the contrary, its delights had become so intoxicating they verged on obsession. In a time when travel was fraught with hardship and peril, Clusius could write of the "great pleasure" his wanderings to "observe plants" had provided.[88] Observation obliterated fear and even pain: when in 1770 the Genevan savant André Deluc, armed with thermometer, hygrometer, and barometer, set out to explore the peaks and glaciers of the Alps, he had a foolproof remedy for vertigo: "There is not the slightest danger for those who do not perceive the increase in height, except by a sort of pleasant sensation, which occurs when one is not afraid, and by the pleasure of continually discovering new objects."[89] Leaves dismembered under the microscope, an aurora borealis spotted after many nights' vigil, thermometer readings faithfully registered in the chill dawn, every day for decades on end—these were pleasures of "discovering new objects" evidently so intense that they tempted Enlightenment naturalists to defy parental counsel, neglect civic duties, and deplete family fortunes.

Although moralists were critical of naturalists who sacrificed their families and their health to a demanding regimen of observation,[90] the naturalists themselves could at least count upon the sympathy of their colleagues, with whom they were in constant, copious, and often commiserating correspondence. Although the publication of observations had become increasingly common by the late seventeenth century, the format by which even printed observations were first communicated was the letter. The Sicilian naturalist Paolo Boccone, for example, chose to publish his observations on coral in 1674 as a series of letters to named correspondents scattered across Europe: the Avignon doctor Pierre Guisony, the Pisa professor of mathematics Alexander Marchetti, the London Fellows of the Royal Society Hooke and Nehemiah Grew.[91] Naturalists had been exchanging observations and specimens among themselves since the sixteenth century, a practice that by the early seventeenth century had cemented a strong sense of community among them.[92]

It was in correspondence that fledgling naturalists apprenticed themselves to recognized masters, as the young Bonnet did to the French naturalist René-Antoine Ferchault de Réaumur and Spallanzani in his turn did to Bonnet, presenting their most precious observations for comment and approval. Observations presented in correspondence were also the way in which one naturalist took the measure of distant colleagues: an insufficiently circumstantial or detailed observation report reflected badly on its author—and conversely. Réaumur, for example, accepted La Hague naturalist Pierre Lyonet's corrections to his own observations on the generation of aphids, bowing to the talents of a master observer and draughtsman: "The figures you have sent me are drawn with such a great air of truth that I believe them to be very perfectly conformable to nature." And in their letters naturalists cheered each other on, comrades in a fellowship scorned by outsiders: when Lyonet was too downhearted to continue to observe insects after his proposal of marriage had been thwarted at the last minute by "a most strange caprice" of the lady's mother, Réaumur remonstrated with him not to give up on insects: "[I]t would be a great pity if you became indifferent to them [insects]; they will not fail to repay the attention you have given them with new marvels that they will make you see. I plead for my good friends."[93]

The sociability of specialized correspondence substituted for the more usual sort, since the demands of strict regimens of observations, like those of religious observances, clashed with those of friends and family. The astronomer Picard, for example, rose at 5:30 a.m. and observed with at most a break of an hour or two until midnight, beginning anew at 5:30 the next morning.[94] By the mid-eighteenth century, observant gentlemen all over Europe were interrupting their daily routines to take thermometer and barometer readings to record in diaries and journals.[95] Weather watching, especially if pursued at fixed times of day, could become a way of life, a regimen that set schedules, shooed guests to the door, and fostered clock consciousness. Tycho contemplated a move to Basel because there, close to France, Germany, and Italy, "it would be possible by correspondence to form friendships with distinguished and learned men in different places," whereas on his property in Knudstrup "a continuous stream of noblemen and friends would disturb the scientific work and impede this kind of study."[96] Réaumur moved out of central Paris to have more room for his beehives and fewer visitors—and where, as Mary Terrall shows in her essay in this volume, he could interweave observation regimens with household routines.[97] For the dedicated observer, normal social life became all but impossible. In his *Traité de météorologie* (1774), the Oratorian and corresponding member of the Académie Royale des Sciences Louis Cotte admitted that the perfect weather observer would have to "renounce almost all other business and every pleasure. Not only would he have to live for years on end in the same place; he would have to be home regularly every day for the hours of his observations."[98]

A shared commitment to observation could, however, forge as well as sever social bonds, even surmounting other barriers to friendly contact. When a group of French Jesuits landed at the Cape of Good Hope on their way to Siam in June 1685, they were greeted with suspicion by the Reformed Dutch colonists, who suspected one of the Jesuits' microscopes (draped with an ornamental cover) of being an outlawed Eucharist chalice "because . . . you are the greatest enemies of our religion." Yet their Dutch hosts were pleased to "lead the life of an observer with us" when the Jesuits measured the longitude by following the satellites of Jupiter, and both parties parted on the warmest of terms, the Jesuits presenting the Dutch with a microscope and a small burning mirror in exchange for gifts of tea and wine.[99] Despite the criticisms of moralists and the warnings of physicians, observers were not so much antisocial as highly selective about the company they kept: although they went to considerable lengths to evade conventional social obligations, they craved contact with other observers, if only by letter. Observation was a solitary and obsessive but also communal pursuit.

Conclusion: Observation as a Way of Reasoning

By the late eighteenth century, the relationship between observation and conjecture had taken yet another turn. As we have seen in chapters 1 and 2, medieval natural philosophers associated observation with conjecture because its results were uncertain, confined to particular instances, and mute concerning causes, while early modern physicians had prized observations just because they were allegedly divorced from foolhardy conjecture and system spinning. In this spirit the Roman professor of medicine Giorgio Baglivi recommended observation as an antidote to "the ardent and eager pursuit of new Hypotheses."[100] But in the course of the eighteenth century, observation became a tool of conjecture, a way of excluding some explanatory hypotheses and hatching new ones, which could in turn be submitted to a new round of observation and often experiment as well. In contrast to late seventeenth-century injunctions to segregate observation and conjecture strictly, mid-eighteenth-century manuals of scientific observation insisted that observation was a way of reasoning about, not just collecting experience: while it was deplorable to observe with prejudice for or against a system, it was utter folly to observe without ideas.[101]

The work of the French naturalist Georges Cuvier illustrates how powerful, sophisticated, and deliberate observation had become by the turn of the nineteenth century and serves as a conclusion to the long story of how observation became an essential way of reasoning in the sciences. Cuvier was celebrated among his contemporaries for his anatomical comparisons of extant and fossil organisms, a form of research that depended on the full armamentarium of techniques and resources developed by scientific observers since the sixteenth century.

In his pioneering monograph on the relation of contemporary African and Indian elephants to fossil pachyderm remains, Cuvier mobilized the well-stocked library and museum in order to construct series, in the sense of both long timelines and arrays of gradually differing specimens. From ancient sources on domesticated elephants to the latest fossil discoveries in Russia and the Americas, Cuvier marshaled an exhaustive list of all previous relevant observations in order to establish the geographic distribution of the species. He attributed particular observations to named individuals, with places, times, and stringent evaluation of reliability, discerning progress in the quality of the more recent observations: in 1577 the Swiss savant Felix Platter had mistakenly identified fossil bones as those of a giant, but Cuvier's esteemed Göttingen colleague Johann Friedrich Blumenbach had recently pronounced them as definitely elephant.

While depending heavily on a community of observers dispersed in space and time, Cuvier voiced his preference for firsthand observation wherever possible, dissecting three elephants himself and having a large drawing made "under my eyes, with much care." Drawings and measurements now counted as essential parts of an observation and were also subject to critical scrutiny. Focusing literally with a magnifying glass trained on fossil teeth, Cuvier inspected minute differences of size, shape, and wear as a function of stage of life. Pages of tables displayed the results of his observations of all the elephant molars he had observed, arranged by minutely noted features such as the length, width, and number of lamia. Amid this elephantine mass of information, ancient and modern, first- and secondhand, literary and visual, qualitative and quantitative, descriptive and tabular, Cuvier sought general, constant features that withstood thousands of comparative observations: "However the size alone of the [fossil elephant's] molars suffices in order to recognize them, because it is much more constant."[102]

For Cuvier and his contemporaries, observation had become a tool to think with, a genuine logic of discovery and proof. It was still collective and *longue durée*, but its practitioners were no longer anonymous nor were its results summarized in proverbs and rules of thumb. The work of observation consisted in collating and comparing the observations of others as well as making one's own. The store of observations burgeoned, repeated by individuals and multiplied by communities. The mission to reveal unsuspected correlations among phenomena persisted, but methods of repetition, note taking, establishing series, and inventing synoptic devices such as tables and maps had replaced what Cicero had called "natural divination."

More than ever before, observation was also an observance, regulating waking and sleeping, looking and overlooking, attention and memory, solitude and sociability. When von Haller, perhaps the most celebrated scientific observer of the Enlightenment, fell gravely ill in 1772, he recorded his own symptoms with the same ingrained habits of noting date and time, counting and measuring, and, above all, repeating an observation once, twice, three times:[103] "At five o'clock in the evening the room was a bit too warm, and there being several people there, I felt very ill, with an intermittent pulse after 1–2 or 3 pulsations. I took acid elixir and had the window opened: the air, although very warm, being a sirocco, had a surprising effect: the pulse immediately regularized itself. Three times I made the same experiment."[104] Observation and observance converged in the practices that remade the observer, body and soul.

Notes

1. See, for example, [Jean-Joseph Ménuret de Chambaud], "Observateur (*Gram. Physiq. Méd.*)," in Denis Diderot and Jean Le Rond d'Alembert, eds., *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers* [1751–80] (Stuttgart and Bad Cannstatt: Friedrich Fromann Verlag, 1967), 11: 310–13; also the three entries (one general, the other two referring to astronomical and medical observation specifically) on "Observation, *Observatio*," in Johann Heinrich Zedler, *Grosses Vollständiges Universal-Lexicon* [1732–50] (Graz: Akademische Druck- und Verlagsanstalt, 1994), 25: 278–87.

2. Charles Bonnet to Albrecht von Haller, Geneva, 22 July 1757, in Otto Sonntag, ed., *The Correspondence between Albrecht von Haller and Charles Bonnet* (Bern: Hans Huber Publishers, 1983), 107.

3. These included *historia*, *casus*, *observatio*, *experimentum*, *experientia*, *phaenomenon*, *factum*. See Arno Seifert, *Cognitio historica. Die Geschichte als Namengeberin der frühneuzeitlichen Empirie* (Berlin: Duncker & Humboldt, 1976); Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995); "Fatti: storie dell'evidenza empirica," ed. Simona Cerutti and Gianna Pomata, special issue, *Quaderni storici* 108, no. 3 (2001); and Gianna Pomata and Nancy G. Siraisi, eds., *Historia: Empiricism and Erudition in Early Modern Europe* (Cambridge, Mass.: MIT Press, 2005).

4. [M. J. A. N. Condorcet], "Éloge de M. Du Hamel," in *Histoire et mémoires de l'Académie royale des sciences. Année 1783* (Paris: Imprimerie Royale, 1785), 131–55.

5. See, for example, Thomas Shadwell, *The Virtuoso* [1676], ed. Marjorie Hope Nicolson and David Stuart Rodes (London: Edward Arnold, 1966); and Jean de La Bruyère, *Les caractères de Théophraste traduit du grec avec les caractères ou les moeurs de ce siècle* [1688], ed. Robert Pignarre (Paris: Garnier-Flammarion, 1965), 338.

6. See the census of keyword frequencies in Marta Fattori, *Lessico del Novum organum di Francesco Bacone* (Rome: Edizioni dell'Atteneo & Bizzarri, 1980), 106–7, 168–74, 208–9, 342.

7. On the Baconian projects, several of them medical, of the Hartlib circle, see Charles Web-

ster, *The Great Instauration: Science, Medicine and Reform, 1626–1660*, 2nd ed. (New York: Peter Lang, 2002).

8. 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: Deutsche Akademie der Naturforscher Leopoldina, 2002), 45–94. Andreas Büchner, *Academia sacri romani imperii Leopoldino-Carolinae naturae curiosorum historia* (Halle and Magdeburg: Johann Gebauer, 1755), 181–97, gives the text of the original bylaws of 1652 (originally published in 1662 under the title *Salve academicum*). Laws 1–8 concern the monographs.

9. Müller, "Die Leopoldina"; Büchner, *Academia*, 194.

10. [Henry Oldenburg], "A Preface to the Third Year of These Tracts," *Philosophical Transactions of the Royal Society of London* 2 (1667): 409–15, on 414; also Mordechai Feingold, "Of Records and Grandeur: The Archive of the Royal Society," in *Archives of the Scientific Revolution: The Formation and Exchange of Ideas in Seventeenth-Century Europe*, ed. Michael Hunter (Woodbridge and Suffolk: Boydell Press, 1998), 171–84.

11. "Nr. 376. Oldenburg to Sachs, 30 May 1665," in A. Rupert Hall and Marie Boas Hall, eds., *The Correspondence of Henry Oldenburg*, 13 vols. (Madison: University of Wisconsin Press, 1965–86), vol. 7 (1670–71), 432–35.

12. Contrast, for example, "Of an Observation, not Long Since Made in England, of Saturn," *Philosophical Transactions* 1 (1665–66): 152–53; or "Observations Concerning Cochineel, Accompanied with Some Suggestions for Finding out and Preparing Such like Substances Out of Other Vegetables," *Philosophical Transactions* 3 (1668): 796–97, with "Some Considerations upon Mr. Reeds Letter . . . in what Sense the Sap May be Said to Descend. . . . ," *Philosophical Transactions* 6 (1671): 2144–49.

13. On the early membership of the Royal Society, see Michael Hunter, "Catalogue of Fellows, 1660–1700," 159–252, in Hunter, *The Royal Society and Its Fellows, 1660–1700: The Morphology of an Early Scientific Institution* (Chalfont St. Giles: British Society for the History of Science, 1982); and for the Académie Royale des Sciences, Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803* (Berkeley and London: University of California Press, 1971), 31–49; *Index biographique de l'Académie des sciences*, 1666–1978 (Paris: Gauthier-Villars, 1979).

14. For example, *Relation d'une observation faite à la Bibliothèque du roy, à Paris, le 12 May 1667, sur les neuf heures du matin, d'un halo ou couronne à l'entour du soleil* (Paris: J. Cusson, 1667); or *Extrait d'une lettre écrite à Monsieur de la Chambre, qui contient les observations qui ont esté faites sur un grand poisson dissequé dans la Bibliothèque du roy, le vingt-quatrième Juin 1667* (Paris: F. Léonard, 1667).

15. Anne-Sylvie Guénon, "Les publications de l'Académie des sciences," in *Histoire et mémoire de l'Académie des sciences. Guide de recherches*, ed. Éric Brian and Christiane Demeulenaere-Douyère (Paris: Technique & Documentation, 1996), 107–40.

16. Procès-verbaux, Archives de l'Académie des sciences, Paris. The manuscript registers begin with the meeting of 22 December 1666.

17. Gianna Pomata, "A Word of the Empirics: The Ancient Concept of Observation and Its Recovery in Early Modern Medicine," *Annals of Science*, forthcoming.

18. Francis Bacon, *Novum organum*, II.xxxvi, in Basil Montagu, ed., *The Works of Francis Bacon*, 17 vols. (London: William Pickering, 1825–34), 9: 375–90.

19. Robert Hooke, "An Attempt to Prove the Motion of the Earth by Observations,"

Lectiones Cutlerianae [1679], reprinted in R. T. Gunther, *Early Science in Oxford* (London: Dawsons, 1968), 8: 4.

20. Bacon, "Distributio operis," *Novum organum*, in *Works*, 9: 173.

21. Bacon, *Novum organum*, II.xlv, in *Works*, 9: 416–17; cp. the table of densities, followed by "Modus experimenti" and "Observationes" in *Works*, 11: 184–92.

22. Bacon, "Phaenomena universi," *Works*, 11: 180.

23. Bacon, *Novum organum*, I.lxx, *Works*, 9: 219–21.

24. On the emergent rhetoric of *experientia/experimentum* in both French and English during this period, see Christian Licoppe, *La formation de la pratique scientifique: le discours de l'expérience en France et en Angleterre, 1630–1820* (Paris: Éditions de la Découverte, 1996), 19–87. The accounts of the experiments performed by the Florentine Accademia del Cimento (roughly, "Academy of Trials"; established 1657) were entitled *Saggi di naturale esperienze fatte nell'Academia del cimento* [1666], rendered as *Essayes of Natural Experiments made in the Academie del Cimento* in the 1684 English translation.

25. Quoted in Hans Poser, "Observatio, Beobachtung," in *Historisches Wörterbuch der Philosophie*, ed. Joachim Ritter and Karlfried Gründer (Darmstadt: Wissenschaftliche Buchgesellschaft, 1984), vol. 6, cols. 1072–81, on col. 1073.

26. See, for example, [Dumarsais], "Expérience," in Diderot and d'Alembert, eds., *Encyclopédie*, 6: 297–98; "Erfahrung," in Johann Georg Wald, *Philosophisches Lexicon* [1778] (Hildesheim: Georg Olms, 1968), 1082–84.

27. [Jean Le Rond d'Alembert], "Expérimental," in Diderot and d'Alembert, eds., *Encyclopédie*, 6: 298–301, on 298.

28. Joseph Priestley, *Experiments and Observations Relating to Various Branches of Natural Philosophy*, 3 vols. (London: J. Johnson, 1779–86), 2: ix. Priestley's experiments on the color of marine acid furnish a striking example of the back and forth between observation and experiment (1: 78–80).

29. One exception was vitalist medicine, whose proponents argued vehemently in favor of observation over experiment: see, for example, [Chambaud], "Observateur (*Gram. Physiq. Méd.*)," in Diderot and d'Alembert, eds., *Encyclopédie*, 11: 310–13, on 312–13.

30. Brian W. Ogilvie, *The Art of Describing: Natural History in Renaissance Europe* (Chicago: University of Chicago Press, 2006), 34–36, 46–44 and passim.

31. Charles Bazerman, *Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science* (Madison: University of Wisconsin Press, 1988).

32. Staffan Müller-Wille, *Botanik und weltweiter Handel: Zur Begründung eines natürlichen Systems der Pflanzen durch Carl von Linné, 1707 78* (Berlin: Verlag für Wissenschaft und Bildung, 1999).

33. Justin Stagl, *A History of Curiosity: The Theory of Travel, 1550–1800* (Chur: Harwood, 1995), 47–52, 126–31. See also chap. 15, this volume.

34. Francis Bacon, *The Great Instauration and New Atlantis*, ed. J. Weinberger (Arlington Heights: Harlan Davidson, 1980), 57.

35. Ogilvie, *The Art of Describing*, 180; Laurent Pinon, "Gessner and the Historical Depth of Natural History," in Pomata and Siraisi, *Historia*, 241–67.

36. British Library, Additional MSS 38, 693. Graham Rees estimates that of some thousand items in the *Sylva*, only twenty-six seem to be based on Bacon's own observations: Graham Rees, "An Unpublished Manuscript by Francis Bacon: *Sylva sylvarum* Drafts and Other Working Notes," *Annals of Science* 38 (1981): 377–412.

37. Charles Nauert, Jr., "Humanists, Scientists, and Pliny: Changing Approaches to a Classical Author," *American Historical Review* 84 (1979): 72–85.

38. See Bacon's strictures against "lazy and haphazard observation," "stupid, vague, and abrupt experiments," and "frivolous and scant natural history." Bacon, "Distributio operis," *Novum organum*, in *Works*, 9: 171–72.

39. Büchner, *Academia*, Law XVII, 194; on the background and adverse reactions (interpreted by some as criticism) to the scholia, see Müller, "Die Leopoldina"; on Bacon's *observationes majores*, see Bacon *Historia vitae et mortis*, in *Works*, 10: 134–45, and *Parasceve ad historiam naturalem et experimentalem*, 11: 423.

40. On the reports of early modern Venetian ambassadors, see Giovanni Comisso, ed., *Gli ambasciatori Veneti, 1525–1792. Relazione di viaggio e di missione* (Milan: Longanesi, 1985).

41. See, for example, the questionnaires of Philip II of Spain (1577), Sir William Petty, and Heinrich Rantzau (1587), all reproduced in Mohammed Rassem and Justin Stagl, eds., *Geschichte der Stadtbeschreibung* (Berlin: Akademie Verlag, 1994), 133–43; 285–93; 157–82; also Justin Stagl, "Vom Dialog zum Fragebogen. Miszellen zur Geschichte der Umfrage," *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 31 (1979): 11–631.

42. Stagl, *A History of Curiosity*, 47–94.

43. [Giovanni Botero], *Relations of the Most Famous Kingdomes and Common-wealths throwout the World*, trans. Robert Johnson, rev. ed. (London: John Haviland, 1630), 1–45. On the Venetian background to Botero's and other compilations of travel reports and their influence on later compilations, see Joan-Pau Rubiés, "Instructions for Travellers: Teaching the Eye to See," *History and Anthropology* 9 (1996): 139–90, on 152–58.

44. Bacon himself had relied heavily on José de Acosta's *Historia natural y moral de las Indies* (1590) for his *Historia ventorum*: Daniel Carey, "Compiling Nature's History: Travellers and Travel Narratives in the Early Royal Society," *Annals of Science* 54 (1997): 269–92. See also Maurizio Bossi and Claudio Greppi, eds., *Viaggi e scienza. Le istruzioni scientifiche per i viaggiatori nei secoli XVII–XIX* (Florence: Leo S. Olschki, 2005); and Daniel Carey, "Hakluyt's Instructions: The Principal Navigations and Sixteenth-Century Travel Advice," *Studies in Travel Writing* 13 (2009): 167–85.

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