Zeitschrift: Archives des sciences [2004-ff.]

Herausgeber: Société de Physique et d'histoire Naturelle de Genève

Band: 67 (2014)

Heft: 2

Artikel: The synoptic scientific image in early modern Europe

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DOI: https://doi.org/10.5169/seals-738383

The Synoptic Scientific Image in Early Modern Europe*

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I. Seeing the Impossible

Historians of Renaissance and early modern European art have long remarked on the many ways in which drawings and paintings gave viewers a glimpse of the impossible. By this I mean not only the obvious examples: images of fabulous creatures like the centaur (Fig. 1) or monstrous hybrids like this man-pig (Fig. 2). Rather, I have in mind more subtle impossibilities, in which the cunning of the artist panders to a certain yearning to see more broadly, deeply, or sharply than located human vision ever could.

Fig. 1. Centaur, Ulisse Aldrovandi, Monstrorum historia *(Bologna, 1642): 31. © Biblioteca Universitaria di Bologna.*

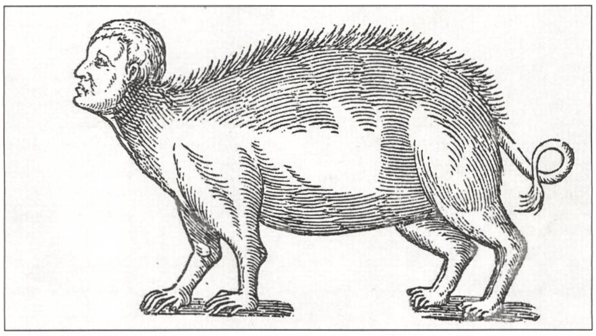


Fig. 2. Man-Pig, Ambroise Paré, Des monstres et prodiges *(1573), éd. Jean Céard (Genève, 1971): 64. Reprinted by permission of the Librairie Droz, Geneva.*

This kind of illusion goes well beyond the *trompe l'oeil* mimesis of the still life, which after all only tricks the eye into thinking that the two-dimensional painting is a three-dimensional arrangement of perfectly possible flowers, fruits, and other objects. Instead, the illusion stretches human vision to superhuman feats of panoramic sweep (Fig. 3)[1], integration of multiple viewpoints (Fig. 4)[2], or simultaneous focusing of foreground and background (Fig. 5)[3]. These are not images of impossible objects but rather of impossible seeing.

In this article, I would like to explore a kind of impossible seeing attempted time and time again in sixteenth- and seventeenth-century natural history, natural philosophy, and even mathematics: synoptic seeing, or seeing everything all at once, in one glance. The "everything" in question could be the patterns of the prevailing winds across the globe or the type of a plant genus emerging from many individual species or the hidden regularities in the fluctuations of the weather or even the essential features of state admin-

1 Marion Hilliges, " Der Stadtgrundriss als Repräsentationsmedium in der Frühen Neuzeit, " in Tanja Michalsky, Felicitas Schmieder and Gisela Engel, eds., *Aufsicht – Ansicht – Einsicht: Neue Perspektiven auf die Kartographie an der Schwelle zur Frühen Neuzeit* (Berlin: trafo Verlagsgruppe, 2009), pp. 351-368, on pp. 354-5; Naomi Miller, *Mapping the City. The Language and Culture of Cartography in the Renaissance* (London: Continuum, 2003), pp. 185-8.

2 Miller, *Mapping the City*, pp. 174-6.

3 James Ackerman, *Distance Points. Essays in Theory and Renaissance Art and Architecture* (Cambridge, MA: MIT Press, 1991), pp. 187-8.

* Adapted from an adress at the award of the Pictet SPHN medal prize held in Palais Eynard, City of Geneva, Geneva the 29th October 2014.

** *Max Planck Institute for the History of Science, Berlin.*

Fig. 3. Jacopo de Barbari, View of Venice (1500). © Trustees of the British Museum.

Fig. 4. Leonardo da Vinci, Plan of Imola (1502), Windsor, Cod. Atl. *12284. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2014.*

istration. In each of these cases, vast amounts of information gleaned from many observers dispersed over centuries and continents had to be distilled into some kind of compact representation: reports from mariners at sea, from generations of botanists, from networks of weather-watchers, or from the stacks of records stored in state archives. The representation in question could be and often was verbal: a terse summary, a list of key points, a short description. But just as often, the representation was visual: a synoptic image that made seeing patterns, essences, and regularities all at once literally possible.

Fig. 5. Albrecht Dürer, Feldhase *(1502). Watercolor, ©Albertina, Vienna.*

The standard term for this kind of taking in of a complex state of affairs all in one glance is the *coup d'oeil*. It originates in an early modern military context of surveying a battlefield from a hilltop or other high vantage point in order to gain a literal overview of a situation that would be a swirling, shouting, bloody confusion of soldiers, horses, carts, and cannons on the ground. By the late eighteenth century, the *coup d'oeil* had become a standard part of the training of military engineers in France, Prussia, and elsewhere.[4] Although military officers disdained the consultation of maps as no substitute for a thorough firsthand survey of the territory[5], we still associate the *coup d'oeil* with the bird's-eye view of a city, of which many early modern examples survive. Historians of cartography have pointed out how these bird's-eye views shade into, on the one hand, landscapes (Fig. 6), and, on the other, views of military fortifications (Fig. 7).[6] What is significant about these bird's-eye views for my purposes is that the impression of the *coup d'oeil*, of seeing everything at a glance, is in fact achieved by seamlessly integrating multiple points of view. No hilltop or church bell tower was ever high enough yet also central enough to give a single observer the entire city in all the desired detail. These bird's-eye view city maps were usually mosaics of multiple views from different vantage points pieced together like parts of a puzzle, a process repeated by the printer who fitted together multiple woodcuts, as in the case of the gigantic Barbari view of Venice (Fig. 3). What the viewer sees is in fact not a bird's-eye point of view but rather more like an angel's-eye point of view, which merges all the individual perspectives into one synoptic image.

I shall argue that this is what early modern scientific images also tried to do: merge many different observations into a synoptic image. Because the kinds of observations were various, so were the images. Tables of weather observations do not look much like botanical illustrations. Yet the very same language of the *coup d'oeil*, of seeing everything at one glance, was repeatedly used in both cases, different as the subject matter and the methods of observation were. Early modern naturalists were confronted with a novel problem that had hardly troubled their predecessors: how to combine multiple observations of the same subject matter – be it a comet, human anatomy, plants, snowflakes, or storms. The synoptic image was one solution. My argument unfolds in three parts: *first*, how combining multiple observations became a problem; *second*, two seventeenth-century examples of how synoptic images were used to solve the problem, one from botany and the other from meteorology; and *third*, some concluding reflections about the kind of impossible seeing these synoptic images provided.

II. Too Much to Observe

Sometime around the middle of the seventeenth century a kind of observational mania seized the European Republic of Letters. In the German city of Schweinfurt, a handful of municipal physicians

4 (Frederick II of Prussia), *Esprit du Chevalier de Foulard tirée de ses commentaires de Polybe* (Berlin: Chrétien-Frédéric Woss, 1761), pp. 1-35.

5 Ibid., p. 19.

6 Miller, *Mapping the City*, pp. 151-158, 179; Hilliges, " Der Stadtgrundriss als Repräsentationsmedium in der Frühen Neuzeit, " p. 355; Daniela Stroffolino, " Rilevamento topografico e processi construttivi delle 'vedute a volo d'ucello', " in Cesare de Seta and Daniela Stroffolino, eds., *L'Europa moderna. Catografia urbana e vedutismo* (Naples: Electa Napoli, 2001), pp. 57-67.

Fig. 6. Albrecht Dürer, Nemesis (Das große Glück) *(1501), over the village of Klausen im Eisacktal. Engraving, ©Albertina, Vienna.*

founded the Academia Naturae Curiosorum and sent out a call to colleagues all over Europe to send in *observationes* of natural rarities, from double refraction to monstrous births, to be published in the academy's aptly named journal, the *Miscellanea curiosa*.[7] (Fig. 8) In Paris the newly installed director of the observatory, the Italian astronomer Gian Domenico Cassini I, opened the first of many bound folio volumes and began recording his observations of everything from lunar eclipses to visits by court dignitaries.[8] Across the city at the Bibliothèque du roi in the Louvre, Claude Perrault and his colleagues at the Académie Royale des Sciences were dissecting animals: ostriches, tortoises, bears.[9] (Fig. 9) In London, natural philosopher and Fellow of the Royal Society Robert Hooke wrote: "there is scarce one Subject of millions that may be pitched upon, but to write an exact and compleat History thereof, would require the whole time and attention of a man's life, and some thousands of Inventions and Observations to accomplish it."[10] (Fig. 10) Everything and anything could be, should be observed – if only there were world enough and time.

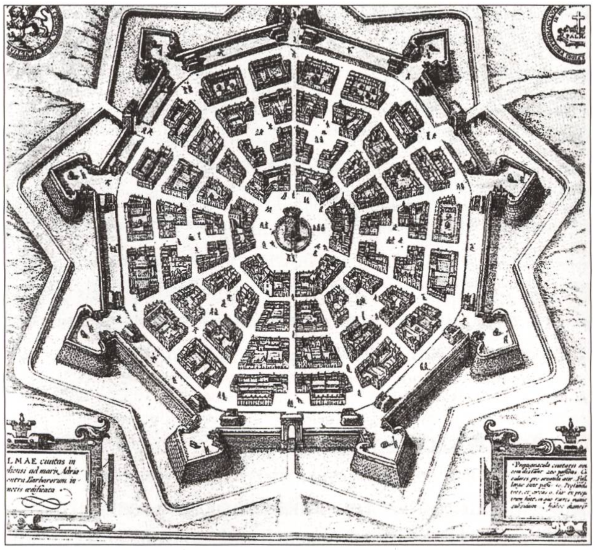


Fig. 7. Palmanova, Georg Braun and Frans Hogenberg, Civitates orbis terrarum *(1598).*

7 *Miscellanea curiosa medico-physica Academiae Naturae Curiosorum*, vol. 1 (Leipzig: Johannes Bauer, 1670); Andreas Büchner, *Academiae Sacri Romani Imperii Leopoldino-Carolinae Naturae Curiosorum Historia* (Halle/Magdeburg: Johann Gebauer, 1755), pp. 193-195.

8 Gian Domenico Cassini I, Journal des observations faites à l'Observatoire 1671-1674, AD 1.1, Bibliothèque de l'Observatoire de Paris; Guy Picolet, " Une visite du jeune Saint-Simon à l'observatoire de Paris," *Cahiers Saint-Simon*, nr. 26 (1998): 59-68.

9 Claude Perrault, " Proiet pour les Experiences et Observations Anatomiques, " (15 January 1667), MS. Proces-Verbaux, vol. 1 (22 December 1666-April 1668), Archives de l'Académie des Sciences, Paris; Académie Royale des Sciences, *Mémoire pour servir à l'histoire naturelle des animaux et des plantes* (Amsterdam: Pierre Mortier, 1736).

10 Robert Hooke, " To the Reader, " *Lectiones Cutlerianae* (1679), reprinted in R.T. Gunther, *Early Science in Oxford*, vol. 8 (London: Dawsons (1931) 1968), n.p.

Fig. 8. Monstrous birth, Johann Georg Greisel, Observatio LV, Miscellanea curiosa medico-physica Academiae Naturae Curiosorum *(Leipzig, 1670): 152. Reprinted by permission of Max Planck Institute for the History of Science, Berlin.*

Nature was vast, various, and variable; experience as limited as the human senses, intellect, and lifespan. The only way to bridge the gap between infinite nature and finite human lifetimes was to create an army of observers, spanning continents and centuries: collective empiricism. The newly formed scientific academies of the seventeenth century like the Academia Naturae Curiosorum (late the Leopoldina, established 1652) or the Académie Royale des Sciences in Paris (established 1666) tried out various models to organize the gigantic work of collective observation. The Academia tried to recruit volunteers who would send in observations from near and far to be published in their journal; the Paris Académie at first performed all observations and experiments together at their meetings; the Royal Society of London (established 1660) combined both forms. Some prophets of the new natural philosophy, such as Bacon and Descartes, thought it would be better to rely on the paid labor of servants to conduct observations and experiments; the academies instead attempted to attract members and correspondents who would work together on a more egalitarian basis. But whatever form collective observation took, multiple observers had to be coordinated and multiple observations had to be combined.

The challenge of integrating multiple observations was still new in the late seventeenth century. During the sixteenth and seventeenth centuries, the nature of observation had been dramatically transformed. What had since Antiquity been a practice associated with what Cicero had called the "natural divination"[11] of sailors, shepherds, and peasants became a prestigious pursuit for scholars. What had throughout the Middle Ages had been a specialized term linked to monastic timekeeping and astrometeorology spread to philology, medicine, jurisprudence, natural history, anatomy, and natural philosophy: by the turn of the seventeenth century, *observationes* and its vernacular cognates featured prominently in titles of scientific and medical treatises, travelogues, humanist compendia, and a great deal that defies ready description, an expansive trend that persisted well into the eighteenth century.[12] *Observatio* and *experimentum*, two words rarely coupled in medieval Latin, became by the latter half of the seventeenth century as inseparable as left and right and, by the mid eighteenth century, were invariably defined in contradistinction to one another, as the foremost forms of "learned experience".[13]

11 Cicero, *De divinatione*, I.vi.

12 Katharine Park, " Observation on the Margins, 500-1500, " Gianna Pomata, " Observation Rising: Birth of an Epistemic Genre, 1500-1650, " and Lorraine Daston, " The Empire of Observation, 1600-1800, " in Lorraine Daston and Elizabeth Lunbeck, eds., *Histories of Scientific Observation* (Chicago: University of Chicago Press, 2011), pp. 15-44, 45-80, 81-113. Based on a preliminary bibliography prepared by Sebastian Gottschalk, using the online catalogues of World Cat, the British Library, the Library of Congress, and the Herzog-August-Bibliothek Wolfenbüttel, and counting titles in Latin, French, Italian, German, and English, circa 82 titles were published 1550-1599, 98 from 1600-1649, 246 from 1650-1699, 681 from 1700-1750, and 1988 from 1751-1800. These figures of course give only a rough indication, but the relative increases are probably reliable.

13 See for example the distinction between " gemeine " and " gelehrte und kluge Erfahrung ", and under the latter heading, between " die Observation " and " das Experiment " in Johann Georg Wald, " Erfahrung ", *Philosophisches Lexicon* (1775), 4th ed. (Hildesheim: Georg Olms, 1968), pp. 1082-84. More generally, see Hans Poser, " Observatio, Beobachtung, " in Joachim Ritter and Karlfried Gründer, eds., *Historisches Wörterbuch der Philosophie* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1984), vol. 6, cols. 1072-1081

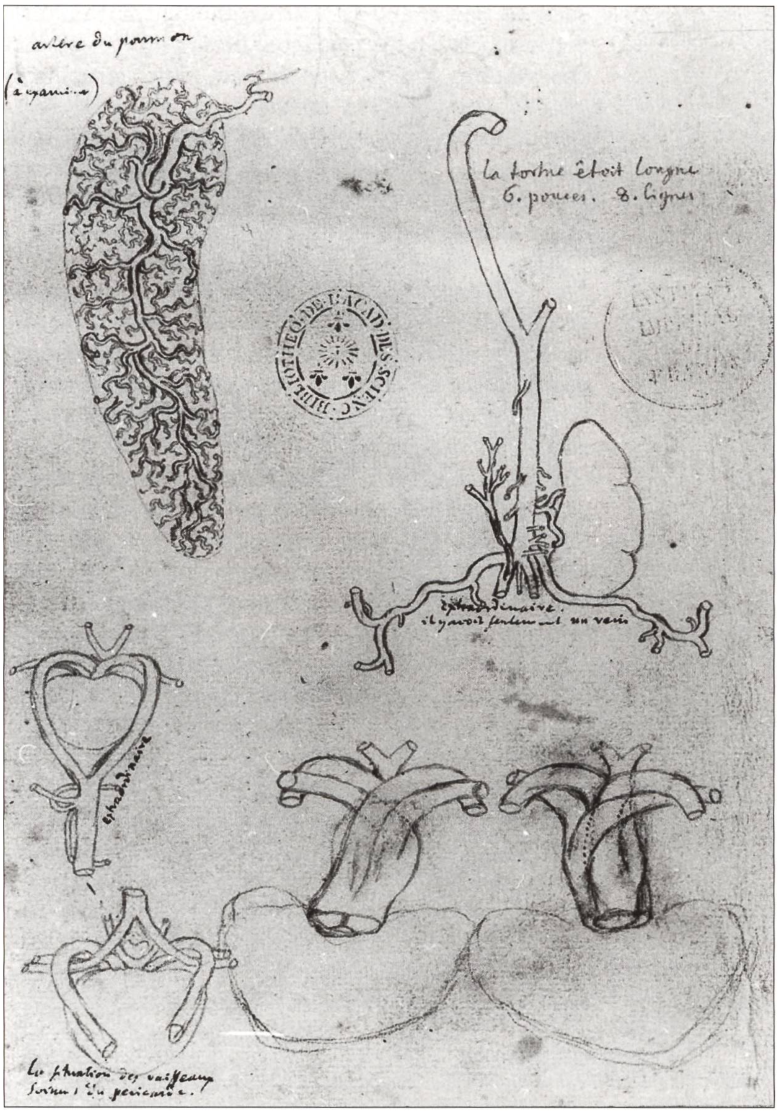


Fig. 9. Tortoise heart and lungs [c. 1667], Sébastien Leclerc, Histoire des animaux, © *Académie des sciences – Institut de France, Paris.*

The emergence of observation as a cultivated form of learned experience had profound epistemic implications that were closely intertwined with the social organization of the early modern European Republic of Letters. Individual savants often conducted their observations by themselves, but they seldom did so for themselves alone. However possessive learned observers might have been of their findings conceived as intellectual or personal property, they understood the significance of their activities in the context of a collective. Sometimes this collective was a literal one, as in the case of the Paris Académie Royale des Sciences that witnessed observations and experiments communally whenever practicable[14]; more often it was a virtual one, called into being by epistolary exchanges, the circulation of manuscripts and publications, lineages of ancestors and successors, or organized networks of far-flung informants armed with instructions and questionnaires. In the context of the multiple early modern movements to reform natural philosophy, empiricism always implied "collective empiricism"[15]: isolated, private observations were meaningless.

Observation had for millennia been imagined as a collective enterprise, but the collective in question had stretched over time, not space: medieval astronomers drew on the observations of Ptolemy, who in turn drew upon those of Hipparchus, who in turn drew upon those of the ancient Babylonians. When Aristotle wrote in *On the Heavens* that the heavenly bodies had since time immemorial traced regular circular trajectories, he was relying on a treasury of observations already

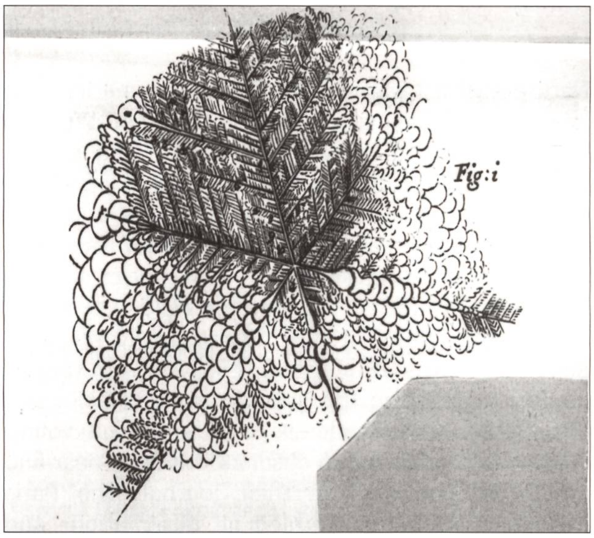


Fig. 10. Crystalline formation in frozen urine, from Robert Hooke, Micrographia: Or some Physical Descriptions of Minute Bodies Made by Magnifying Glasses *(London 1665).*

14 *Mémoires de mathématique et de physique. Année MDCXCII. Tirez des registres de l'Académie Royale des Sciences* (Amsterdam, 1723), "Avertissement", sig. 2r; Denis Dodart, *Mémoires pour servir à l'histoire des plantes* (Paris: Imprimerie royale, 1676), "Avertissement", n.p.

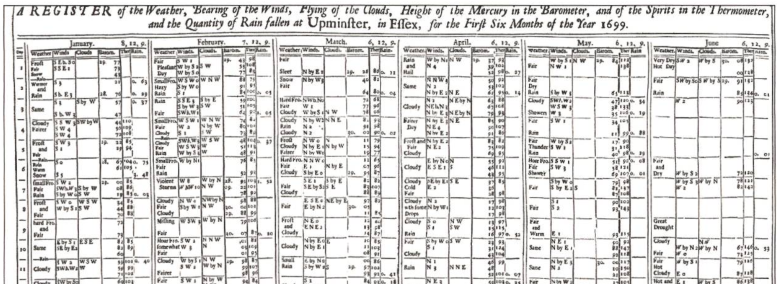
15 Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007), pp. 19-27.

Fig. 11. Lilium acadiense pumilum, *drawn by Nicolas Robert, from Denis Dodart,* Mémoires pour servir à l'histoire des plantes *(Paris, 1676). ©Muséum national d'Histoire naturelle (Paris) - Direction des bibliothèques et de la documentation.*

many centuries old.[16] This was a literate tradition, and astronomical observations were sometimes individually attributed, as in the case of Hipparchus – a sign of how rare and precious they were, costly in terms of time, money, and skill. In contrast, the observations of natural phenomena encoded in proverbs about the weather, navigation, and farming were anonymous and orally transmitted, but they too accreted through the slow, cumulative labor of generations upon generations.

The challenge to self-consciously scientific experience in the latter half of the seventeenth century was to create a super-observer, compounded of many individual observers scattered over time and space. It was not enough for scientific academies like the Academia Naturae Curiosorum or the Royal Society of London or the Paris Académie Royale des Sciences to recruit scores of volunteers to send in observations on all and sundry to be published in their annals – the observational mania described above. Nor would it suffice for each observer to use the finest instruments, to insist upon firsthand inspection of the phenomena, to take scrupulous notes, and to write meticulous descriptions. The observations had to be knit together in order to permit the work of sifting and comparison, the elimination of errors and accumulation of facts, and to go forward. Individual experience had to be melded into collective experience, individual observers into the super-observer who straddled continents and centuries like a colossus.

[16] Aristotle, *On the Heavens*, I.iii, 270b12. It was believed that Egyptian and Babylonian records went back hundreds of thousands of years: Aristotle, *On the Heavens*, trans. W.K.C. Guthrie, Loeb Classical Edition (Cambridge, Mass.: Harvard University Press, 1971), p. 24-5n.


A REGISTER of the Weather, Bearing of the Winds, Flying of the Clouds, Height of the Mercury in the Barometer, and of the Spirits in the Thermometer, and the Quantity of Rain fallen at Upminster, in Essex, for the First Six Months of the Year 1699.

January. February. March. April. May. June

Fig. 12. Weather Table from William Derham, "Part of a Letter from the Reverend Mr Derham to Dr Sloane, Giving an Account of His Observations of the Weather for the Year 1699," Philosophical Transactions *22 (1700-1): 527-529.*

III. Two Examples: Botanical Illustrations and Weather Tables

The super-observer produced the synoptic image. Here are two very different examples, one from the Académie Royale des Sciences in Paris and the other from the Royal Society of London, both from the late seventeenth century: (Figs. 11, 12). These images not only look different; some might object to calling the weather table an image at all. And they were certainly produced by different methods. Nonetheless,

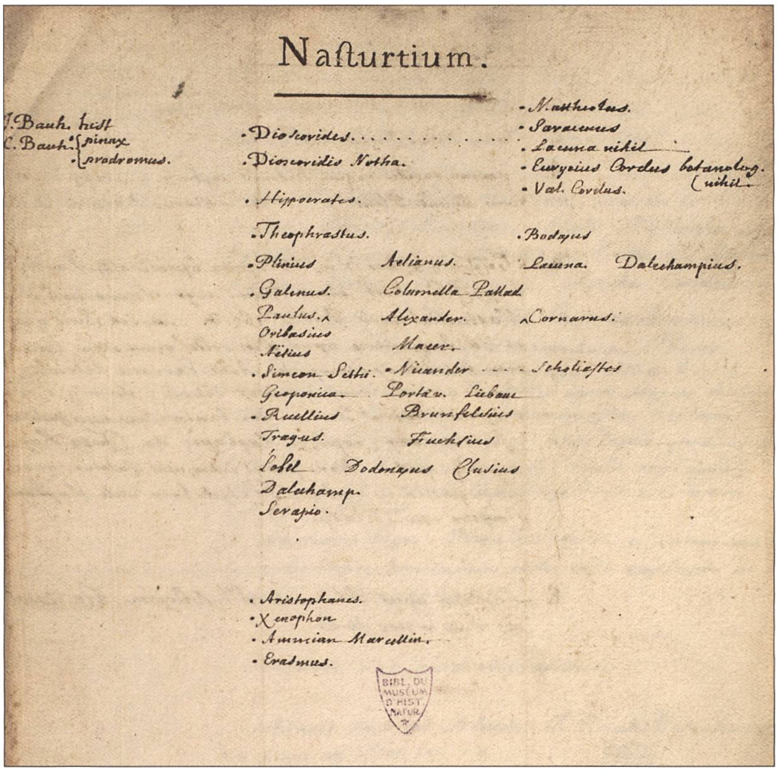


Fig. 13. "Nasturtium," MS 450, Muséum national d'Histoire naturelle, Paris. © Muséum national d'Histoire naturelle (Paris) - Direction des bibliothèques et de la documentation.

both aimed to compress the results of many observations into a compact visual object that could be seized at a glance. How was this done?

Consider the case of the botanical illustration. In January 1667, less than a month after the Parisian Académie Royale des Sciences had held its first official meeting, the architect and physician Claude Perrault proposed ambitious projects in comparative anatomy and botany.[17] At the Académie's quarters in the Bibliothèque du Roi in the rue Vivienne, a team of anatomists, assisted by several artists, dissected a camel, a bear, a chameleon, a pelican, an ostrich, and other such animals as came their way, usually via a death at the royal menagerie.[18] Across town at the Jardin du Roi, botanists and artists under the direction of physician and academician Denis Dodart meticulously described live plants cultivated in the garden or herbarium specimens collected from far and wide.

In the projects undertaken by seventeenth-century scientific academies, the community of observers embraced the near and the distant, the living and the dead: not only the academicians, their artists, and their dispersed correspondents, but also past naturalists stretching back to Antiquity. Although one explicit motivation for both Paris Académie projects was to correct the errors of older authorities like Pliny and Dioscorides, their works were still regularly consulted as part of the compilation of observations that made comparisons and generalizations possible. (Fig. 13) The manuscript title page for the entry "Nasturtium" of the *Histoire des plantes* lists all of the ancient and modern botanical works consulted in its preparation, just as the most oft-consulted early modern botanical reference work, Caspar Bauhin's *Phytopinax* (1596) commenced with registers of both authors cited and correspondents who had sent in specimens, botanists past and present alphabetized by first name, Aristotle rubbing shoulders with "Felix Platter doctor from Basel" and

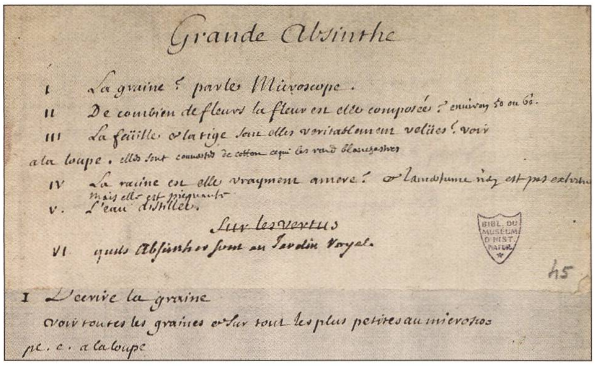


Fig. 14. "La Grande Absinthe," MS 450, Muséum national d'Histoire naturelle, Paris. ©Muséum national d'Histoire naturelle (Paris) - Direction des bibliothèques et de la documentation.

[17] Claude Perrault, "Proiet pour les Experiences et Observations Anatomiques," 15 janvier 1667, Procès-Verbaux, t. 1 (Registre de physique, 22 décembre 1666-avril 1668), pp. 22-30; and idem, "Projet pour la Botanique," ibid., pp. 30-38. Archives de l'Académie des Sciences, Paris. 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 15 January 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 Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences* (Berkeley: University of California Press. 1990).

[18] Alice Stroup, *A Company of Scientists:* on 39.

"Ulisse Aldrovandi doctor from Bologna."[19] A manuscript instruction from the Paris Académie's natural history of plants project exhorts artists and assistants: "I repeat what I have said before: it is absolutely necessary before starting to work on the description of any plant whatsoever that has already been described and figured to look at as many of these descriptions and figures as possible."[20]

The hands and eyes (and sometimes the tongues and noses) of all the observers of the natural history of plants projects were coordinated by close supervision and constant correction. Stacks of manuscript instructions, now preserved at the Bibliothèque du Muséum national d'Histoire naturelle (the successor institution of the Jardin du Roi), reveal how the senses of the botanists and artists were schooled to see, taste, and describe in unison. Each sheet is headed with the name of a plant species and contains detailed queries and replies. Take this typical example of queries relating to wormwood (Fig. 14). The questions direct the attention of the observer by demanding closer investigation ("I. La graine? par le microscope."), requesting further details ("III. La feülle et la tige sont elles vertitablement velües? voir a la loupe."), or directing the observer to focus more sharply on color, texture, and taste ("IV. La racine est elle vrayment amere?").

The copious and exacting instructions, paired with the laconic and occasionally dissenting replies in different hands, bear witness to a struggle between ways of seeing, touching, smelling, and tasting. Were the roots of the *Aconitum salutiferum* fringed or furry (as Camerarius had figured them)? Were the tips of the *Geranium Robertianum primum* brown, yellow, or brown dusted with yellow pollen? What did the *Aconitum flore Delphinii* smell like? Did the roots of *Fraxinella officinis* taste insipid or bitter? The style of seeing and describing enforced by these queries and instructions was relentlessly comparative: not only were artists and assistants sternly reminded to consult all previous descriptions and figures in older botanical works before beginning their own; the single most oft-repeated exhortation was to repeat an observation, both to check that of a predecessor or to sharpen one's own.

The syntheses achieved by the *Histoire des plantes* depended on such comparisons, corrections, and repetitions. The final product, description and figure, ideally extracted the essential traits of the plant, depicted its principal parts in all stages of development, portrayed it as close to life-size as folio format permitted, and offered magnified views of details and

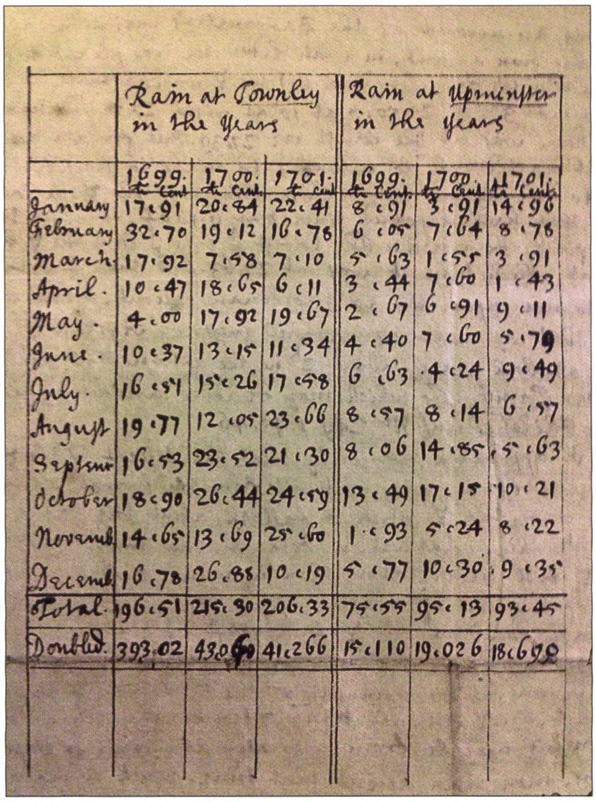
March. 6, 12, 9.

Weather	Winds.	Clouds.	Barom.	Ther	Rain.
Fair					
Sleet	N by E 2		29. 26	86	0. 12
Snow	N by W 3		40	82	
Fair					
			64	80	0. 04
Hard Fro.	N W b. N o		72	68	
Fair	W 1		77	96	
Cloudy	W by S 1	N W	78	96	
Cloudy	N by W 2	N N E	82	93	
Rain	N 2		91	98	
Cloudy	N 2		30. 02	90	0. 02
Froſt	N W o	N	11	79	
Cloudy	N by E 1	N by W	15	94	
Fairer	N by W o		19	77	
Hard Fro.	N N W o		11	65	
Fair	E 1	N by E	07	96	
Cloudy	S by E o		29. 95	87	
	S E 1	S by E	82	82	
Fair	S E by S 2	S E	83	107	
Cloudy			88	89	
	E S E o	NE by E	97	82	
Fair	E by N 2		30. 05		
			11	85	
Froſt	N E o		12	80	
and	E N E 2		13	98	
Cloudy			14	87	
	N by E o	E	10	85	
Cloudy	N by E 1		11	103	
			08	91	
Small	E by N o		00	86	
Rain	S by W 2	S	29. 97	102	
			93	92	0. 41
	S 1		84	93	0. 18
Cloudy	S by W 1		84	106	
			78	97	
Rain	S by W 1		63	93	0. 01
	S by E 1		58	102	
Fairer			69	88	1. 68
Froſt	W o		80	81	
Fair					
Cloudy			84	108	

Fig. 15. Table for March 1697, William Derham, "Register of the Weather, etc. for the Year 1697," Philosophical Transactions *20(1698): 45-8.*

[19] Caspar Bauhin, *FUTOPINAX, seu Enumeratio plantarum herbarijs nostro seculo descriptarum, cum earum differentijs* (Basel: Sebastian Henripetrus, 1596), n.p. (following "Praefatio").

[20] (Denis Dodart?), "A l'occasion de la figure de Camerarius je repete ce que j'ay dit autre fois qu'il est absolument necessaire avant que de travailler a quelque description que ce soit d'une plante déia décrite et figurée de voir le plus qu'on pourra de descriptions et de figures." "Aconitum salutiferum sive Anthora Aconit salutaire ou Anthora," MS 450, Muséum national d'Histoire naturelle, Paris.



	Rain at Townley in the Years			Rain at Upminster in the years		
	1699.	1700.	1701.	1699.	1700.	1701.
January	17.91	20.84	22.41	8.91	3.91	14.96
February	32.70	19.12	16.78	6.05	7.64	8.76
March	17.92	7.58	7.10	5.63	1.55	3.91
April	10.47	18.65	6.11	3.44	7.60	1.43
May	4.00	17.92	19.67	2.67	6.91	9.11
June	10.37	13.15	11.34	4.40	7.60	5.79
July	16.54	15.26	17.58	6.63	4.24	9.49
August	19.77	12.05	23.66	8.57	8.14	6.57
Septemr	16.53	23.52	21.30	8.06	14.85	5.63
October	18.90	26.44	24.59	13.49	17.15	10.21
Novemb	14.65	13.69	25.60	1.93	5.24	8.22
Decemb	16.78	26.88	10.19	5.77	10.30	9.35
Total	196.51	215.30	206.33	75.55	95.13	93.45
Doubled	393.02	430.60	41.266	15.110	19.026	18.690

Fig. 16. Rainfall at Townley and Upminster (1699-1701), William Derham to John Houghton, 5 April 1703, Early Letters D1/52, Royal Society, London. © The Royal Society.

dissections. The precondition for this verbal and visual composite observation was the prior tutelage of the senses that discerned, the hand that drew, and the mind that judged and described. Dodart achieved the combination of observations by a training process that resembled the apprenticeship of artisans.

Now let us return to the second example, the weather table. On 7 October 1663 Robert Hooke read a proposal to the Royal Society of London " (f)or the making of a more accurate history of the change of the weather... ". Observers were not only told what to look at (the winds, heat and cold, the "colour and face of the sky" and how (e.g. assessing moisture with "a good hygroscope"); they were also instructed on how to register and display their observations. In order to lay hold of "this Proteus", the ever-changing weather, observers should "have a large book in folio ruld into severall columns, and each of these columns to be markd overhead w[th] the name of w[t] particulars are to be registered... ". Hooke's memo[21] does not include a template illustration, but presumably the tables sent in from the Royal Society's most faithful weather watcher, Anglican divine and F.R.S. William Derham of Upminster in Essex followed up on Hooke's instructions. (Fig. 15)

From such a table, Hooke explained, "one may be able at one view as it were to see all of the Schem or platforme of the weather for a whole month... ".[22]

The aim of a natural history of weather was to be able to predict the future on the basis of observations of the past. Although some early modern observers hazarded causal explanations of why, for example, the barometer rose in foggy weather[23], most followed Derham's lead in leaving such speculations to others.[24] The table of weather observations was used not only for the taking and keeping of data; it also was understood as a method of discovery of such correlations: between barometer readings and impending storms; between hot and cold spells and the incidence of distempers; between winds and the inclination of the magnetic needle. Since the early nineteenth century such relationships have been depicted as graphs; since the early twentieth century, as statistical correlations. But in the late seventeenth and early eighteenth centuries, tables were the preferred visual tool for discerning and testing possible connections between the weather and everything from the phases of the moon to the eruptions of Vesuvius.

Tables could also potentially draw together phenomena scattered across space as well as time. Seventeenth-century observers were dimly aware of weather patterns at a continental or even global scale (as in the case of Halley's 1686 map of the worldwide system of winds[25]). After comparing the temperatures at Zurich, and Upminster, Derham concluded that England got Zurich's weather after a few days' delay.[26] Derham's friend and fellow-observer Richard

21 See Thomas Sprat, *History of the Royal Society* (London: J. Martyn, 1667), pp. 173-179.

22 Robert Hooke, " For the making a more accurate history of the changes of weather ..., " (1663), Royal Society of London Archives, Classified Papers, v. 20 (Hooke Papers), Nr. 24.

23 John Wallis, " Observations Continued upon the Barometer, or rather Balance of the Air... " *Philosophical Transactions* 1(1665-66): 163-166.

24 " Whether the Observations my Register is filled with, will be of any use, to judge of the Fertility, or Scarcity, the Healthiness, or Diseases, or any other occurrences of the last, or of former, or future years, I shall leave to the much better judgments of You & the rest of the learned Members of your Hon[ble] Society. " William Derham to Hans Sloane, 23 January 1699/1700, Royal Society Archives, Early Letters/D1/49; printed in *Philosophical Transactions* 22(1700-1): 527-529.

25 Edmond Halley, " An Historical Account of the Trade Winds, and Monsoons, observable in the Seas between and near the Tropicks, " *Philosophical Transactions* 16(1686-92): 153-168.

26 W. Derham, J.J. Scheuchzer, and Michel Angelo Tilli, " Tables of the Barometrical Altitude at Zurich in Switzerland in the Year 1708 ", *Philosophical Transactions* 26 (1708-9): 334-336, on p. 345.

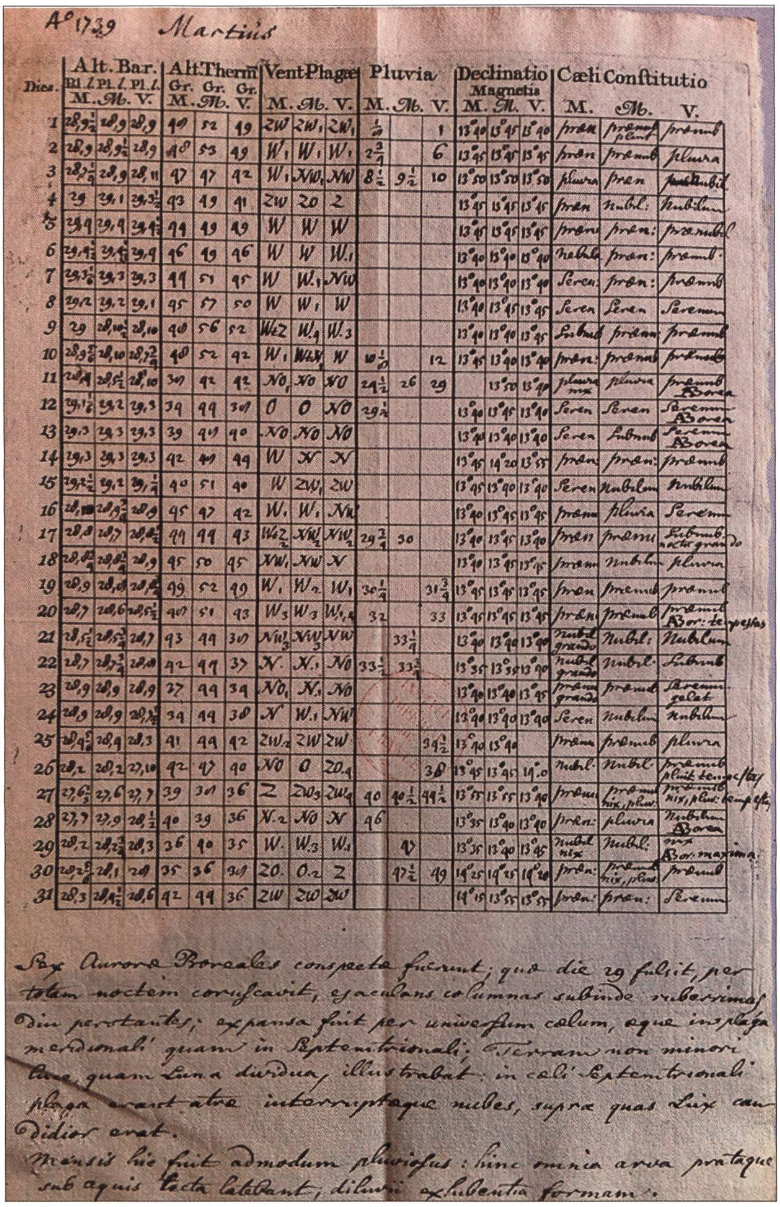


Fig. 17. Pieter van Musschenbroek, "Ephemerides meteorologicae leydenses annorum 1739 et 1740", Dossier Musschenbroek, Archives of the Académie des Sciences, Paris. ©Académie des Sciences – Institut de France, Paris.

Towneley of Lancastershire concluded from a comparison of weather tables that the barometer rose and fell all over Britain in unison.[27] (Fig. 16)

Using tables to see through time, correlating past and present, and space, correlating near and far, depended crucially on visual skills: how to construct, display, and read tables so that subtle connections leapt to the eye? Every column in the weather tables was at once a record of observation and a hypothesis to be tested. Pieter van Musschenbroek, professor first at Utrecht and then at Leiden and perhaps the most diligent of the meteorological correspondents of both the Royal Society and the Paris Académie, constructed his tables with columns for barometer, thermometer, winds, rainfall, constitution of the sky – and magnetic declination. (Fig. 17) The latter was conjectural: did the wild swings of the needle of the magnetic compass bear any relationship to the similarly erratic changes in wind direction or air pressure? In a 1729 letter to the Royal Society, Musschenbroek admitted that, so far, neither wind nor "have fair Weather, Rain, Snow or Storms any effect on the magnetical Virtue: whereof look into the Table, & you'l be confirm'd."[28] Yet who knew how many years of observation would be needed to discern some subtle correlation among the entries in the columns? Musschenbroek did not lose hope in his magnetic observations, as his table submitted to the Paris Académie a decade later shows.

If the eye was to be able to survey the entire table at a glance, however, limits had to be set to complexity and sprawl. Such visual constraints also pushed table-makers to develop abbreviations and still more compact symbols, though standardizing these proved just as difficult as standardizing any other aspect of weather observation, from instruments to format to number and content of columns. Musschenbroek thought his elaborate symbols would be "at first sight easily underst(ood)" but nonetheless provided a legend. (Fig. 18) Despite Musschenbroek's optimism concerning the intelligibility of his symbols, the density and heterogeneity of these ingeniously constructed tables must have baffled the eye: how to make sense of the rows and columns of numbers, words, and symbols in one sweeping, panoramic glance, as Hooke and so many other early modern naturalists yearned to do?

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27 R. Towneley, " An Account of What Rain at Townly in Lancashire, in the Years 1697 and 1698, with Some Other Observations on the Weather ", *Philosophical Transactions* 21(1699): 47-48.

28 Pieter van Musschenbroek, " Meteorological, Barometrical, Thermometrical, Epidemical, and Magnetical Ephemerides written at Utrecht ... in the Year 1729 ", Royal Society, Classified Papers, IV(2)/6.

Fig. 18. Pieter van Musschenbroek, Detail of "Explicatio Signorum", "Meteorological ... Ephemerides" (1729), Classified Papers IV.2/6, Royal Society, London. © The Royal Society.

Weather tables could be read in right-angle fashion, by scanning down the leftmost column for a date and then moving rightwards along that row to ascertain the thermometer, barometer, or hygroscope measurements for that day. But tables could also be be surveyed in *coup d'oeil* fashion, like a landscape viewed from a hilltop, so that regularities invisible at valley-level (or buried in single rows and columns) would snap into focus. In other words, the tables could be scanned like an image, not just read like a text. Ideally, a correlation, a periodicity, or some other pattern would crystallize visually, in the way that the thousands of multi-colored dots that compose a pointillist painting coalesce into a composition when viewed from the right distance. Whether these correlations would be between today's weather in Zurich and the day-after-tomorrow's weather in Upminster, or between the new moon and low barometer readings, or between magnetic declination and the prevailing winds was all a matter of conjecture. Anything and everything might be relevant. The super-vision to which the weather-watchers aspired embraced time and space at the scale of generations and continents, but the actual visual skills required to achieve it were those of surveying a table compressed into a single page.

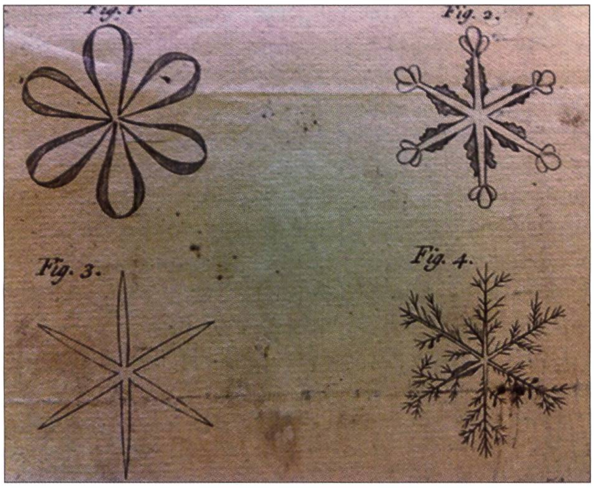

Fig. 19. Detail of "rosaceous, stellated" snowflakes observed under a microscope, "Meteorological ... Ephemerides" (1729), Classified Papers IV.2/6, Royal Society, London. © The Royal Society.

The fate of Musschenbroek's tables at both the Royal Society and the Paris Académie provides some insight into the challenges posed by this kind of seeing and how they were met. Of all the late seventeenth and early eighteenth-century weather tables printed in the annals of the London and Parisian scientific societies or preserved in their archives, Musschenbroek's are among the most elaborate in terms of their construction and most compendious in terms of the number and variety of observations they contain. In contrast to Derham, who might leave off observing for weeks at a time as his travels and personal affairs dictated, Musschenbroek recorded his observations not just every day without exception but indeed three times a day, morning, noon, and night. As we have seen, he devised a whole hieroglyphics to represent data on everything from fog to thunder. He tracked the rise and fall of the barometer with a kind of proto-graph. Moreover, he included pages and pages of further observations that could not be shoehorned into his tables, like the unusual shape of snowflakes that fell on 6 January 1729 (Fig. 19).

Yet at both the Royal Society of London and the Paris Académie Royale des Sciences Musschenbroek's fantastically detailed observations and tables languished in the archives, never to see the light of print. The more jam-packed the table, the harder it was to survey like an image. Paradoxically, the effort devoted to compressing data into brief entries and symbols may actually have decreased rather than increased their visual intelligibility. Had all the weather-watchers adopted the same visual conventions, perhaps a form of tabular literacy might have developed. Modern eyes gratefully absorb the several attempts to present barometer fluctuations graphically, as in the case of the table sent to the Royal Society by the Dutch land surveyor Nicolaas Kruik (Fig. 20). But there is no evidence that early modern eyes found these displays perspicuous; at least such conventions seem to have been occasionally reinvented but not imitated. Tables rarely fulfilled Hooke's hopes of being grasped at a glance.

There were however exceptions. When Leibniz published his table of "binary arithmetic" in 1703, he included a table displaying Base 2 and Base 10 equiv-

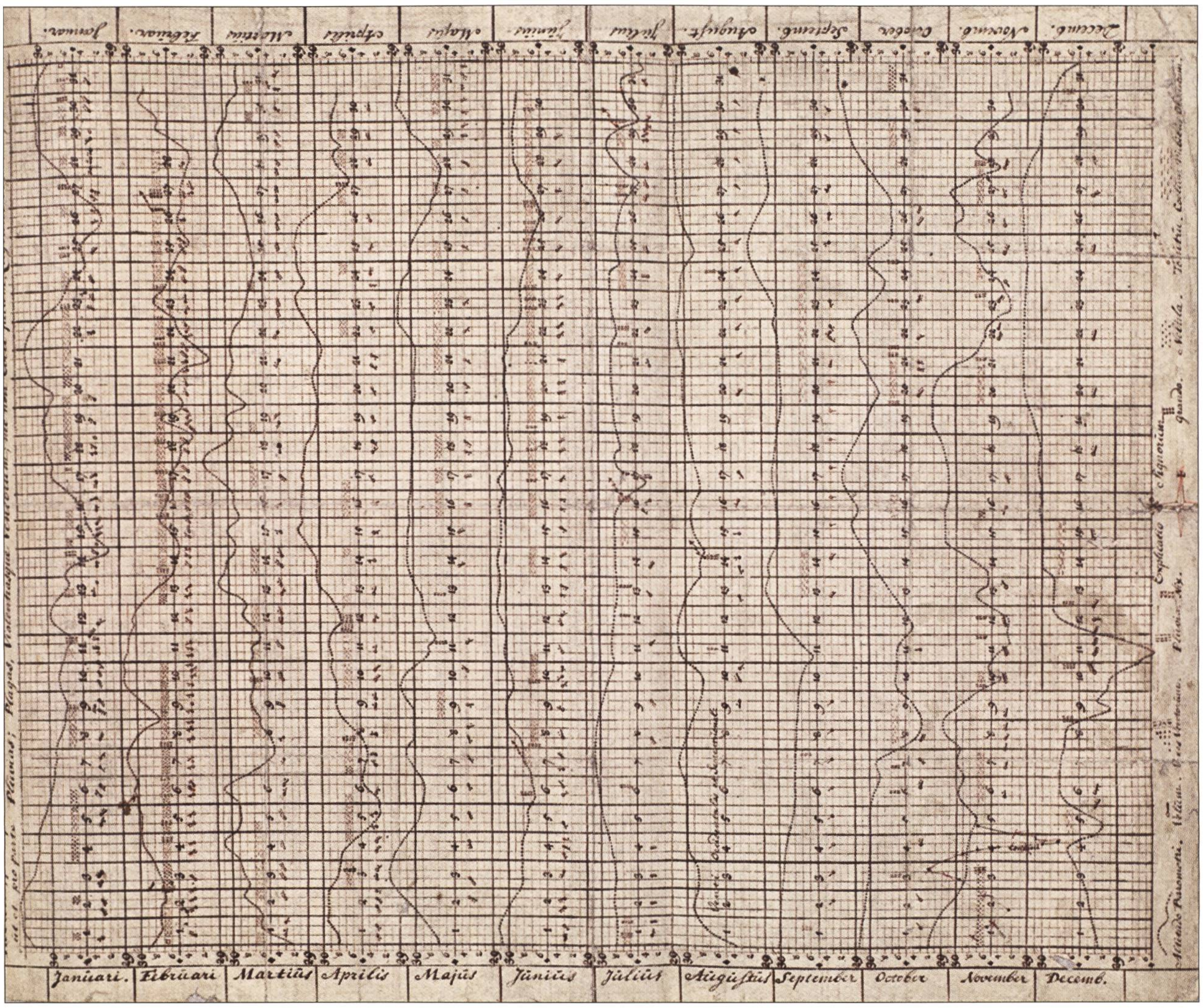

Fig. 20. Nicolaus Cruquius, "Observationes ... Lugduni Batavorum", Classified Papers 5/19, Royal Society, London. © The Royal Society.

alents, to be read in the usual right-angle fashion. (Fig. 21) However, Leibniz also instructed readers scan his table more holistically, in order to discover a property of geometric progressions: "One sees here at a glance (*d'un coup d'oeil*) the reason for a *celebrated property of the double (i.e. squared) geometric progression* of whole numbers ...". Leibniz did not recommend switching to Base 2 arithmetic, since the numbers would be longer and therefore more cumbersome than their Base 10 equivalents. Binary arithmetic, as set forth in his table, was rather a method of "new discoveries" in mathematics – for example of periodicities (e.g. of squares and cubes) in the columns, which Leibniz had carefully set off by inserting zeroes to "fill up the blank spaces" in his table.[29] Even a mathematical table could be read in *coup d'oeil* fashion, in search of cycles and correlations, just as Hooke had hoped to read the weather tables.

IV. Conclusion: Prelapsarian Vision

This was not the first time that Leibniz had tried to visualize heaps of data by seeing them all in one view. At about the same time as Hooke was instructing Royal Society weather watchers, Leibniz wrote a memo to an unnamed prince proposing a "Table of the State (*Staatstafel*)" that would digest all the information gathered in the royal archives into a one-page synopsis that would make everything "easy to find but also what belongs together *visible in a*

[29] Gottfried Wilhelm Leibniz, " Explication de l'arithmétique binaire, qui se sert des seuls caracteres 0 & 1, avec les Remarques sur son utilité, & sur ce qu'elle donne le sens des anciennes figures Chinoises de Fohy", *Mémoires de l'Académie Royale des Sciences. Année 1703* (Paris: Chez Jean Boudot, 1705), pp. 85-89, on pp. 85-86.

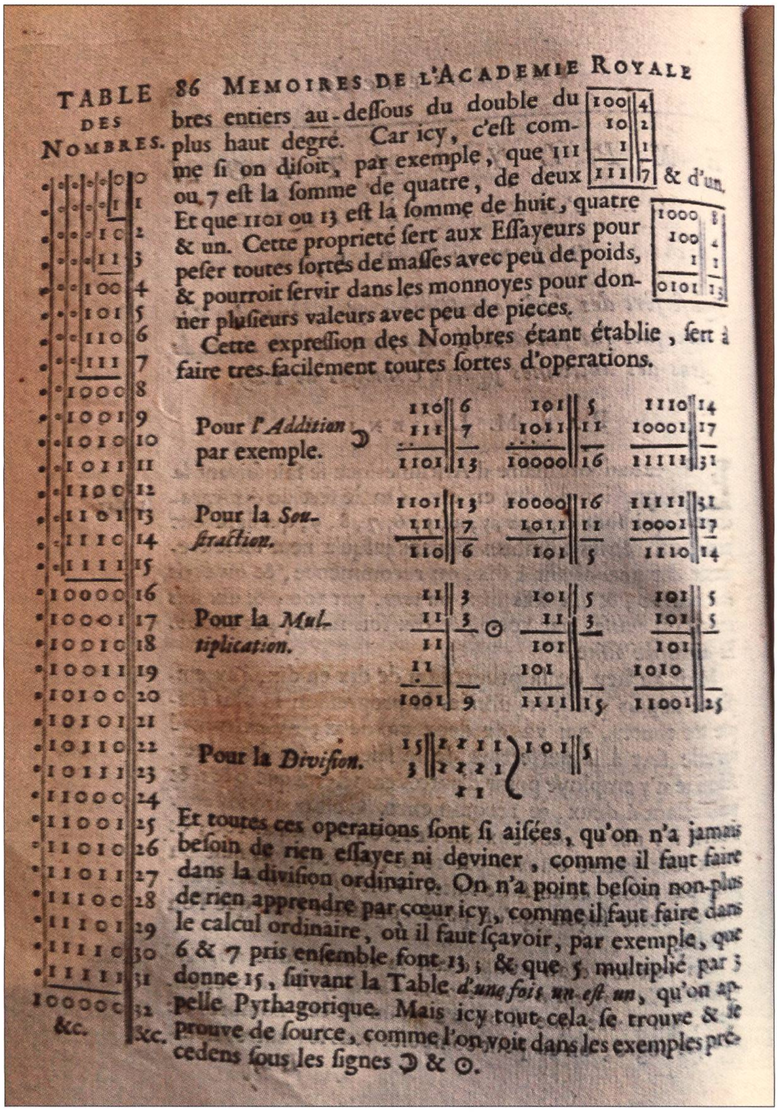

TABLE DES NOMBRES.

0 0
1 1
10 2
11 3
100 4
101 5
110 6
111 7
1000 8
1001 9
1010 10
1011 11
1100 12
1101 13
1110 14
1111 15
10000 16
10001 17
10010 18
10011 19
10100 20
10101 21
10110 22
10111 23
11000 24
11001 25
11010 26
11011 27
11100 28
11101 29
11110 30
11111 31
100000 32
&c. &c.

86 MEMOIRES DE L'ACADEMIE ROYALE

bres entiers au-dessous du double du plus haut degré. Car icy, c'est comme si on disoit, par exemple, que 111 ou 7 est la somme de quatre, de deux & d'un. Et que 1101 ou 13 est la somme de huit, quatre & un. Cette proprieté sert aux Essayeurs pour peser toutes sortes de masses avec peu de poids, & pourroit servir dans les monnoyes pour donner plusieurs valeurs avec peu de pieces.

100 4 / 10 2 / 1 1 / 111 7

1000 8 / 100 4 / 1 1 / 1101 13

Cette expression des Nombres étant établie, sert à faire tres-facilement toutes sortes d'operations.

Pour l'Addition par exemple. ☽ 110 6 + 111 7 = 1101 13; 101 5 + 1011 11 = 10000 16; 1110 14 + 10001 17 = 11111 31

Pour la Soustraction. 1101 13 − 111 7 = 110 6; 10000 16 − 1011 11 = 101 5; 11111 31 − 10001 17 = 1110 14

Pour la Multiplication. ⊙ 11 3 × 11 3: 11, 11, 1001 9; 101 5 × 11 3: 101, 101, 1111 15; 101 5 × 101 5: 101, 1010, 11001 25

Pour la Division. 15 / 3: 1111 / 11 = 101 5

Et toutes ces operations sont si aisées, qu'on n'a jamais besoin de rien essayer ni deviner, comme il faut faire dans la division ordinaire. On n'a point besoin non-plus de rien apprendre par cœur icy, comme il faut faire dans le calcul ordinaire, où il faut sçavoir, par exemple, que 6 & 7 pris ensemble font 13; & que 5 multiplié par 3 donne 15, suivant la Table *d'une fois un est un*, qu'on appelle Pythagorique. Mais icy tout cela se trouve & se prouve de source, comme l'on voit dans les exemples precedens sous les signes ☽ & ⊙.

Fig. 21. Gottfried Wilhelm Leibniz, " Explication de l'arithmétique binaire ... ", Mémoires de l'Académie Royale des sciences. Année 1703 *(Paris, 1705): 85-89.*

moment."[30] Like so many of Leibniz's brilliant and wacky projects, this one was never realized.[31] But one catches echoes of the ambition to see everything all at once in the most unexpected places among the annals of early modern science and philosophy. Descartes, for example, fretted about how the long deductions in mathematical demonstrations made such arguments no better than mere enumerations. Real certainty could be obtained only when the mind could grasp the proof as a whole, "take(n) in at one glance," without having to depend on memory.[32] Bacon also recommended the making of "tables"(by which he meant ordered lists) because "natural and experimental history is so various and diffuse that it distracts and confounds the understanding."[33] Wherever memory buckled under an unbearable load of information, the longing to see everything all at once was resurgent.

The faculty that came to the aid of over-worked memory was called "intuition", a faculty associated since the thirteenth century with the cognition of angels in the works of Bonaventure and Thomas Aquinas.[34] Just what intuition was and how it worked was a matter upon which learned opinions diverged, but almost all commentators were agreed that it was lightning fast, dazzlingly clear, and indubitably certain. Memory had been the faculty cultivated by Renaissance humanists, who were fond of pointing out that Mnemosyne, the goddess of memory, was the mother of the muses in Greek mythology. But by the mid-seventeenth century, even the most titanic memory could no longer keep up with the avalanche of printed books tumbling from the printing press or the flood of observations being sent from all over the world to sci-

30 " Alles aber nicht allein leicht zu finden, sondern auch was zusammengehört, gleichsam *in einem Augenblick zu übersehen...* " Gottfried Wilhelm Leibniz, " Entwurf gewisser Staatstafeln, " in Mohammed Rassen and Justin Stagl, eds., *Geschichte der Staatsbeschreibung. Ausgewählte Quellentexte 1456-1813* (Berlin: Akademie Verlag, 1994), pp. 319-329, on p. 325. On Baroque tables of the sort Leibniz might have had in mind, see Cornelia Vissmann, *Akten: Medientechnik und Recht* (Frankfurt am Main: Fischer, 2001), pp. 204-217.

31 Matthew L. Jones, *The Good Life in The Scientific Revolution: Descartes, Pascal, Leibniz, and the Cultivation of Virtue* (Chicago: University of Chicago Press, 2006), p. 240, describes Leibniz's fascination with tables in many contexts.

32 René Descartes, *Rules for the Direction of the Mind* (comp. 1628), in John Cottingham, Robert Stoothoff, and Dugald Murdoc, trans., *The Philosophical Writings of Descartes*, 2 vols. (Cambridge: Cambridge University Press, 1985), vol. 1, Rule III, pp. 14-5; cp. Matthew L. Jones, *The Good Life in The Scientific Revolution: Descartes, Pascal, Leibniz, and the Cultivation of Virtue* (Chicago: University of Chicago Press, 2006), p. 27.

33 Francis Bacon, *Novum organum* (1620), Bk. II, Aphorisms X-XV.

34 David Keck, *Angels and Angelology in the Middle Ages* (Oxford: Oxford University Press, 1998).

Fig. 22. Model for Pavia Cathedral (1488- ca. 1507). Musei Civici del Castello Visconteo, Pavia. From: Ausstellungskatalog Architekturmodelle der Renaissance, *Bernd Evert (ed.) (München, 1995): 226.*

entific academies. In 1680, Leibniz cursed "that horrible mass of books that keeps on growing"[35]; the secretaries of the Royal Society and the Académie Royale des Sciences must have sometimes felt the same way about the observations stacked up in their archives. Bookish scholars invented compendia, indices, tables of contents, headings, and other devices to manage their information overflow, but the naturalists hoped that intuition would come to their rescue in the form of the synoptic image.

Like the orrery that contracted the solar system to a table-top toy or the architectural model that shrunk a cathedral to dollhouse size (Fig. 22), the synoptic image recaptured the swift, sure confidence of ordinary perception for extraordinary objects: the type of a plant species; the patterns of the weather.

[35] Quoted in Ann M. Blair, *Too Much to Know: Managing Scholarly Information before the Modern Age* (New Haven: Yale University Press, 2010), p. 58.

However arduous the processes of making and integrating collective observations, its early practitioners hoped thereby to restore the scale and immediacy of everyday experience – but for objects that were scattered over continents and centuries, spread out in series, or pieced together from fragmentary reports. To describe their efforts as "data management" or "information processing" fails to capture the distinctly early modern yearnings for a prelapsarian or even angelic form of vision that knew by flashes of intuition, not by plodding discourse or long vigils of repeated observations: the longing to see everything, all at once, and all together in one synoptic image.