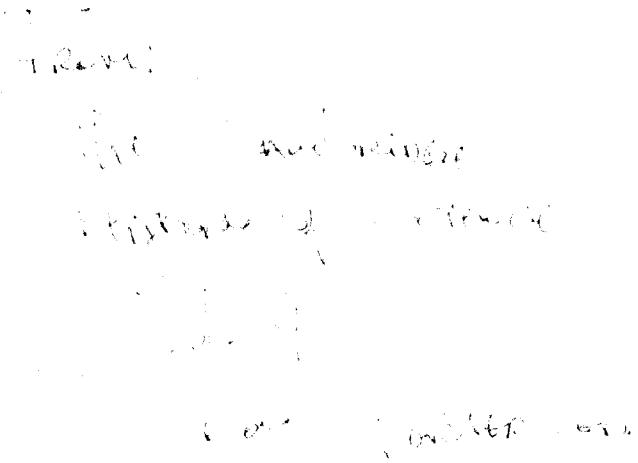

10

CLASSIFYING THE SCIENCES

Richard Yeo

Since Plato and Aristotle, philosophers of the Western tradition have placed a premium on the organization of knowledge. When knowledge is ordered, subdivided, and controlled we speak of trees, fields, maps, and bodies – metaphors suggesting definite structures and relationships. When knowledge is regarded as chaotic, overwhelming, or undifferentiated, we speak of labyrinths, mazes, or oceans – still perhaps implying that an order exists but acknowledging that it is not yet visible. The ancient philosophers endorsed the first, and positive, side of this dichotomy in two related ways: first, by privileging logically demonstrable, or at least systematically organized, bodies of knowledge as *scientia* or science, distinguishing them from other forms of knowledge, such as opinion, craft, or technical skills (*techne*); second, by seeking to demonstrate how the various sciences are related, in some rational manner, to one another in an overarching classification of knowledge. These maps or charts indicated appropriate paths of education and learning. Schemes of this kind were produced by the scholastic thinkers of the Middle Ages and they informed, and were themselves reinforced by, the pedagogy and curricula of the universities through to the Renaissance and beyond.[1] To travel one of these paths was to master the "encyclopedy," the circle of sciences.

By the eighteenth century there had been significant changes in the social and cultural conditions that supported these earlier classifications of knowledge. For example, the universities were no longer the only avenue to knowledge, especially to information about science and the useful arts. But for at least the first half of the century, the terminology in which the sciences were discussed was still close to that of scholastic philosophy. Exposure to the formal language of textbooks, dictionaries, and scientific lectures of this period

[1] James A. Weisheipl, "The Nature, Scope and Classification of the Sciences," in David C. Lindberg (ed.), *Science in the Middle Ages* (Chicago: University of Chicago Press, 1978), pp. 461–82.

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can be a disturbing experience for the uninitiated. Words such as "Physicks" (and its apparent double, "Physick"), "Physiology," "Pneumaticks," "Pneumatology," "Phytology," "Somatology," and "Aerology" regularly occur in works apparently addressed not only to scholars but also to the reading public. At the same time, as the editors of *The Ferment of Knowledge* insist, far from being a stagnant period after the excitement of the Scientific Revolution, this century saw the consolidation of inquiry into the phenomena of electricity, magnetism, and heat, the revolution in chemistry, historical theories of the solar system, and the appearance of new subjects such as geology, biology, and psychology.[2] But it is precisely these developments, which appear reassuringly "modern," that make it crucial to resist any easy importation of later disciplinary categories into the discussion of eighteenth-century science. It is helpful to see these advances in two ways: first, the increasing success of the physico-mathematical sciences on the Newtonian model, such as astronomy, mechanics, and optics; second, the accumulation of empirical observations of the kind Francis Bacon (1561–1626) had called for in relatively new areas of inquiry, such as electricity, magnetism, physiology, and mineralogy, and in the taxonomy of the plant and animal kingdoms. This explosion of knowledge – by no means confined to the natural sciences – strained the old terminology and some of the classifications it embodied. It made new maps of knowledge necessary, while at the same time making them difficult to draw.

There can be no doubt, however, that the exercise appealed to a range of thinkers. Consider the prospect of the French philosopher, Antoine-Louis-Claude Destutt de Tracy (1754–1836), sitting in a prison at les Carmes in July 1794. Only a few days before his expected trial and possible death by guillotine, he struggled to work out a classification that would show the unity of the sciences.[3] This episode might be taken as an appropriate coda for a century that has often been seen as manifesting a passion for classification and universal systems. Yet it is also significant that Destutt de Tracy concluded that if there was a universal science, or a unity of the sciences, it rested on physiology rather than mathematics – thus inverting the position of thinkers such as Descartes and other progenitors of the Enlightenment movement.

Two points can be drawn from these observations: the first, and well-known one, is that the ancient quest for the unity of the sciences continued in the eighteenth century; the second is that there was only limited agreement about how the natural or physical sciences should be classified; moreover, the prospect of achieving a consensus was complicated, and diminished, by the end of the century as new scientific disciplines – such as Destutt de Tracy's favourite, physiology – emerged as largely autonomous fields of inquiry. When historians

[2] G. S. Rousseau and Roy Porter (eds.), *The Ferment of Knowledge: Studies in the Historiography of Eighteenth-Century Science* (Cambridge University Press, 1980), p. 2.

[3] Emmet Kennedy, "Destutt de Tracy and the Unity of the Sciences," *Studies on Voltaire and the Eighteenth Century*, 171 (1977), 223–39. Tracy survived and soon became a member of the new national Institut.

of the Enlightenment attempt to epitomize its intellectual character, this issue inevitably appears. Norman Hampson, in *A Cultural History of the Enlightenment,* suggested that the eighteenth century "regarded knowledge as a whole, rather than as a collection of separated parts." But this remark sits somewhat uncomfortably beside Thomas Hankins' comment in his *Science and the Enlightenment:* "The creation of the new scientific disciplines was probably the most important contribution of the Enlightenment to the modernization of science, and one that we might easily overlook."[4] These two attempts at generalization reflect the complexity of the question they imply: how did eighteenth-century thinkers perceive the relationships between the various sciences? How did they draw their maps of knowledge?

In logical terms, classification of knowledge involves assumptions about the demarcation of sciences from one another as discrete categories as well as views about relationships between various sciences, perhaps revealing an underlying unity. Classification implies division. But since the ancients there have been different, often coexistent, stresses on unification and division in classifying knowledge. The Aristotelian tradition divided the sciences into speculative or theoretical; practical; and artistic or productive, and within these, distinguished clearly between sciences in terms of subject matter and method. John Locke (1632–1704) followed a version of this in his *Essay Concerning Human Understanding* (1690), assigning the "sciences" to three groups: physics, ethics, and logic. But in reviewing this work in *New Essays Concerning Human Understanding* (1704), Gottfried Wilhelm Leibniz (1646–1716) argued that such divisions were arbitrary. Earlier, in 1679, he had remarked, "It does not make much difference how you divide the sciences, for they are one continuous body, like the ocean."[5] Thus, the conviction of unity did not necessarily require discrete categories, and it is thus not surprising to find an emphasis on either unity or diversity in eighteenth-century writers and in the work of historians studying them.

Whether the sciences were conceived philosophically as ultimately one or many, people of the eighteenth century did not share our modern sense of the scope and boundaries of scientific subjects. They certainly did not recognize the closely differentiated array of disciplines, often marked by special journals

[4] Norman Hampson, *A Cultural History of the Enlightenment* (New York: Pantheon Books, 1968), p. 86; Thomas Hankins, *Science and the Enlightenment* (Cambridge University Press, 1985), p. 11.

[5] Gottfried W. Leibniz, *Philosophical Writings* (London: J. M. Dent, 1995), ed. G. H. R. Parkinson, trans. M. Morris and G. H. R. Parkinson, p. 6. On the Aristotelian tradition, see James A. Weisheipl, "Classification of the Sciences in Medieval Thought," *Medieval Studies*, 27 (1965), 54–90, at 58 -68; Charles Schmitt, *Aristotle and the Renaissance* (Cambridge, MA: Harvard University Press, 1983); William A. Wallace, "Traditional Natural Philosophy," in Quentin Skinner and Eckhard Kessler (eds.), *The Cambridge History of Renaissance Philosophy* (Cambridge University Press, 1988), pp. 210–35. For the problems seen by seventeenth-century thinkers, see Lorraine Daston, "Classifications of Knowledge in the Age of Louis XIV," in David L. Rubin (ed.), *Sun King: The Ascendancy of French Culture during the Reign of Louis XIV* (London: Associated University Presses, 1992), pp. 207–20. More generally, see Robert McRae, *The Problem of the Unity of the Sciences: Bacon to Kant* (Toronto: University of Toronto Press, 1961).

and institutions, that began to emerge in the early nineteenth century. Even the names of some modern disciplines, such as biology and geology, did not exist in the early part of the century; and of course, other names, such as "Physics," rather than denoting the set of subjects recognized today, usually referred to the entire study of causes in nature.[6] Aristotle called this "natural philosophy" and gave it higher status than mathematics, which he regarded as a subject dealing in abstract concepts that must be adjudicated by those searching for real causes in nature – namely, by the natural philosopher. The term still carried some connotations from its original meaning – a search for qualitative explanations based on the essential nature of bodies. For example, in a German encyclopedia (initiated in 1732 by Johann Zedler), the entry on "*Natur-Lehre*" recommended that physics be confined to the study of material objects but conceded that some people preferred the older view of it as also encompassing the properties of spiritual entities. But the dominant trend was a strengthening of the nexus forged between mathematics and natural philosophy during the preceding century and culminating in the work of Isaac Newton (1642–1727). This upset the Aristotelian subordination of mathematics to natural philosophy.[7] Another consequence of this nexus was the generally lower status accorded to nonquantitative studies of nature that did not boast the experimental method and mathematical formulation of the new natural philosophy. These observational and taxonomic studies were collectively called natural history, and in the century from 1660 to 1760 they represented at least 19 percent of the research activity within science, even though they accounted for only 4 percent of university chairs in science, the majority of which were in the established fields of mathematics, medicine, and natural philosophy.[8]

In an important essay on the array of sciences bequeathed to the eighteenth century from earlier periods, Thomas Kuhn distinguished between classical (mathematical) and experimental (Baconian) sciences. The former, he suggested, consisted of an uncontroversial "natural cluster" of five sciences – astronomy, harmonics, mathematics, optics, and statics (or mechanics) – those named by Aristotle as "the more physical parts of mathematics." Although practitioners of these sciences acknowledged a role for experiments, Kuhn contended that these were of a limited kind and were often "thought experiments" used as a jumping-off point for mathematical theories or, if actually performed, usually served to demonstrate a conclusion known in advance. In contrast, for the "Baconian" sciences of the seventeenth century, experimentation was preeminent, directed toward seeing "how nature would behave under previously unobserved, often previously nonexistent, circumstances." For Kuhn, this second category of sciences embraced a range of empirical inquiries, some of which were already commonly identified with named sciences, such as chemistry, whereas others were phenomena for new systematic investigation, such as electricity, magnetism, and heat. The Baconian sciences were associated with a new set of instruments for use in making and registering observations: microscopes, thermometers, barometers, air pumps, detectors of electric charges. Unlike the classical sciences, these fields were not marked by "a body of consistent theory," although their practitioners began systematically to concentrate their research around well-defined phenomena.[9]

Kuhn's analysis is useful in underlining the fact that the "sciences" of the eighteenth century were not all of one piece. In fact, it was the classical/mathematical disciplines – to use his typology – that unproblematically qualified as sciences in the older sense of *scientia*, a meaning still endorsed by Samuel Johnson (1709–1784) in his *Dictionary of the English Language* of 1755. Thus, in Kuhn's account there was a body of mature, relatively stable sciences and another, more diffuse, group of subjects that pursued the Baconian program of collection, observation, and experiment but were not yet marked by strong consensus around a dominant theory. This view also allows a distinction between significant advances within physico-mathematical sciences, such as the wave theory of light in optics, and the consolidation of new areas of inquiry, such as those in physiology and geology.

What has been said so far indicates some of the issues historians of science have identified while trying to capture eighteenth-century assumptions. But how did contemporaries perceive the sciences? Did the appearance of what historians now see as new fields of inquiry, or significant advances within established subjects, lead to any reconfiguration of accepted maps of knowledge? We can answer only if we have a picture of how eighteenth-century thinkers regarded natural knowledge and how they placed it in relation to other parts of knowledge.

CLASSIFICATION IN PRACTICE

Where did thinking about classification of knowledge take place? The anecdote about Destutt de Tracy suggests that the ancient philosophical practice

[6] See Benjamin Martin, *The Philosophical Grammar*, 2nd ed., 1738 [1st ed. 1735], (London: J. Noon), part 4, for use of "Geology"; but here it embraced not only the "terraqueous globe" but also vegetation and animal bodies. See Roy Porter, *The Making of Geology: Earth Science in Britain 1660–1815* (Cambridge University Press, 1977)

[7] *Grosses vollständiges Universal Lexicon*, 64 vols. (Halle: J. H. Zedler, 1732–50), vol. 23, column 1149. On mathematics and natural philosophy, see Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1996), pp. 35–8, 161–8; John Henry, *The Scientific Revolution and the Origins of Modern Science* (London: Macmillan, 1997), pp. 18–21.

[8] John Gascoigne, "The Eighteenth-Century Scientific Community: A Prospographical Study," *Social Studies of Science*, 25 (1995), 575–81, at 577–8.

[9] Thomas S. Kuhn, "Mathematical versus Experimental Traditions in the Development of Physical Science," in *The Essential Tension: Selected Studies in Scientific Tradition* (Chicago: University of Chicago Press, 1977), pp. 31–65, quotations at pp. 37, 47. See also Dear, *Discipline and Experience*, 168–79.

of discerning relationships – logical links, order of study, hierarchies of prestige – among subjects was alive and well at the end of the century. But there seems to be agreement that, by contrast with the centuries that preceded and followed, the contribution of the eighteenth century to the philosophical tradition of classifying the sciences was minor.[10] The writers who addressed this topic largely followed the earlier work of Bacon (1561–1626), Thomas Hobbes (1588–1679), Locke, or Leibniz, who in turn were either in agreement or dispute with Aristotle. This tradition was stronger in Germany than in France or Britain. Christian Wolff (1679–1754) and Immanuel Kant (1724–1804) saw it as important, but it is probably fair to say that no major philosopher made classification of the sciences his dominant preoccupation in the style of nineteenth-century writers such as Auguste Comte and Herbert Spencer; no natural philosopher of this period devoted such attention to this exercise as the French savant Andre-Marie Ampère (1775–1836). Indeed, the widespread distrust of "*esprit de système*" – associated with Aristotelian scholasticism and its metaphysical systems, and with Cartesianism – also led many writers to question the value of grand schemes of classification. And the variety of such schemes on offer began to encourage statements about their relative and arbitrary character.[11] Nevertheless, in spite of this skepticism, there were other practical imperatives that kept classification alive as an issue in a number of situations.

According to one commonplace image of the period, such an interest in classifying the sciences is to be expected. Noticing the passion for taxonomy in natural history – most obviously associated with Carl Linnaeus's (1707–1778) *Systema Naturae* (1735) and *Philosophia Botanica* (1751) – some writers have seen a drive to classify as indicative of a pervading thought style. In this perspective, both Linnaeus' works on natural history and encyclopedism are seen as contemporaneous and parallel classificatory projects – quests to name and order the world, both the Book of Nature and the circle of human learning.[12] Indeed, it is true that both projects assumed that this could be done by summarizing knowledge in textual form in a manner that was, in principle, universally accessible. In fact, George-Louis Leclerc comte de Buffon's (1707–

[10] See Robert Flint, *Philosophy as Scientia Scientiarum and a History of Classification of the Sciences* (Edinburgh: Blackwood, 1904); R. G. A. Dolby, "Classification of the Sciences: The Nineteenth Century Tradition," in Roy. F. Ellen and David Reason (eds.), *Classifications in Their Social Context* (London: Academic Press, 1979), pp. 167–93; Nicholas Fisher, "The Classification of the Sciences," in R.C. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge (eds.), *Companion to the History of Modern Science* (London: Routledge, 1989), pp. 853–68.

[11] G. Tonelli, "The Problem of the Classification of the Sciences in Kant's Time," *Rivista critica di storia della filosofia*, 30 (1975), 244–94, at 265; Ernst Cassirer, *The Philosophy of the Enlightenment*, trans. F. Koelln and J. Pettegrove (Princeton, NJ: Princeton University Press, 1979), p. vii.

[12] Gunnar Broberg, "The Broken Circle," in Tore Frängsmyr, J. L. Heilbron, and Robin E. Rider (eds.), *The Quantifying Spirit in the 18th Century* (Berkeley: University of California Press, 1990), pp. 45–71, at pp. 45–6; see also Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (London: Tavistock, 1970), pp. 125–65.

1788) *Histoire Naturelle*, published from 1749 (with supplements by collaborators), grew to forty-four volumes by 1804, making it far larger than most encyclopedias. Both the systems of natural history and the compilations of knowledge in encyclopedias were conceived and explained as places of display – cabinets, museums, libraries, compendia – through which a larger, external universe could be sampled and understood. Writing about the *Encyclopédie*, Bernard Groethuysen captured this capacity of the *philosophes* to survey man's intellectual estate as if it were a newly discovered land:

> The objects which we have assembled and which are found sometimes in a certain part of the island, sometimes in another, it is we who have collected and put them in the order which suits us, placing them in such and such a room of this universal museum which our *Encyclopédie* represents.[13]

The suggestion here is that the *philosophes* were audacious enough to arrange knowledge as they liked, rather than following any traditional system. As we shall see, this was indeed an issue, and one that also had its analogy in the debate over natural versus artificial taxonomic systems in natural history. In both cases, the question of whether classification was arbitrary was heightened by the problem of fitting expanding information into fixed categories of a nomenclature.

In more recent scholarship, the eighteenth century has been seen as the starting point of some phenomena that have reached their peak, or crisis point, in our own time. Some historians have argued that leisure, consumerism, and information were significant issues in modern Western society before the late twentieth century, and they regard the eighteenth century as a watershed.[14] Since the 1970s, the notion of an information revolution has been common in discussions of contemporary cultural crises. But it is also possible to speak of an "information explosion" in the eighteenth century, one that was associated with the massive circulation of printed material encouraged by an increasingly literate audience and the energies of print capitalism. As early as 1680 Leibniz confessed anxiety about the "horrible mass of books which keeps on growing," so that it would soon be a disgrace rather than an honor to be an author. Peter Burke has suggested that a pressing concern with ordering and managing this information was reflected in three areas: the role of journals as filters of information; the practical need for cataloging

[13] Bernard Groethuysen, cited in Herbert Dieckmann, "The Concept of Knowledge in the *Encyclopédie*," in Herbert Dieckmann, Harry Levin, and Helmut Motekat (eds.), *Essays in Comparative Literature* (St. Louis, MO: Washington University Studies, 1961), pp. 73–107, at pp. 84–5.

[14] For this literature, see Neil McKendrick, John Brewer, and J. H. Plumb, *The Birth of a Consumer Society: The Commercialization of Eighteenth-Century England* (London: Europe Publications, 1982); John Brewer and Roy Porter (eds.), *Consumption and the World of Goods* (London: Routledge, 1993); John Brewer and Ann Bermingham, *The Consumption of Culture, 1600–1800: Image, Object, Text* (New York: Routledge, 1995).

of libraries; and the attempts at comprehensive summaries of knowledge in encyclopedias.[15] Although journals, libraries, and encyclopedias predate the eighteenth century, it is important to note that in this period they became more explicitly linked to the problems of organizing and selecting knowledge, by this time seen not merely as abstract philosophical issues but also as practical problems for all educated readers.

If we take the example of encyclopedias, we can say that there *was* something distinctive about the issue of the classification of knowledge in the eighteenth century. This era saw the emergence of the modern form of dictionaries and encyclopaedias – in vernacular languages – that sought to present the circle of sciences, both ancient and modern, to a readership wide enough to support the massive commercial investment they required. Beginning with the English dictionaries of arts and sciences by John Harris (1667?-1719) (*Lexicon Technicum,* 2 vols, 1704 and 1710) and Ephraim Chambers (1680?-1740) (*Cyclopaedia,* 2 vols, 1728), this reached a climax in the French *Encyclopédie* (1751) – the symbolic text of the Enlightenment – and concluded with the *Encyclopaedia Britannica* (3 vols, 1768–71), which started as three volumes but reached eighteen by 1797.[16] This was a period in which the various branches of knowledge were laid out on paper in a manner supposedly accessible to people outside the formal university system. For this reason, it is possible that the task of classifying sciences, placing them in relation to one another and choosing the most relevant for particular purposes, was made more public than it had ever been. Whereas a twelfth-century encyclopedist, Hugh of St. Victor (c. 1096–1141), advised his readers to learn everything because nothing was superfluous, the editors of the eighteenth-century works admitted that the full compass of arts and sciences could not be embraced by individual minds.[17] From this followed the need to select, but in doing so, to recognise the sector of the circle in which one was moving, to appreciate which subjects lay near by.

[15] Gottfried W. Leibniz, "Precepts for Advancing the Sciences and Arts," in Philip P. Wiener (ed.), *Leibniz: Selections* (New York: Scribner's, 1951), pp. 29–30; Theodore Roszak, *The Cult of Information: The Folklore of the Computer and the True Art of Thinking* (New York: Pantheon, 1986); Peter Burke, "Reflections on the History of Information in Early Modern Europe," *Scientiarum Historia,* 17 (1991), 65–73.

[16] The *Encyclopédie,* edited by Jean Le Rond d'Alembert (1717–1783) and Denis Diderot (1713–1784), began as a translation of Chambers' *Cyclopaedia,* projected first as four and then twelve volumes when it began to appear in 1751 but eventually becoming a dramatically larger work comprising seventeen volumes of text and eleven of plates by its completion in 1772. This was followed by four supplemental volumes of text, one supplemental volume of plates, and two supplemental volumes of index, 1776–80.

[17] The editors of the *Encyclopédie* explained that their project was unthinkable without the participation of many contributors. See Jean Le Rond d'Alembert, *Preliminary Discourse to the Encyclopedia of Diderot,* translated with an introduction by Richard N. Schwab (Chicago: University of Chicago Press, 1995), p. 3. On Hugh of St. Victor, see Pierre Speziali, "Classification of the Sciences," in Philip Wiener (ed.), *The Dictionary of the History of Ideas: Studies of Selected Pivotal Ideas,* 5 vols. (New York: Scribner's, 1968–74), vol. 1, p. 464.

MAPS OF SCIENCES IN ENCYCLOPEDIAS

I will focus the rest of this chapter on encyclopedias as a manageable way of approaching a number of questions about the way contemporaries regarded their intellectual landscape. Was there any consensus about the major divisions of knowledge? Where did natural knowledge – the object of what we now call "sciences" – lie on these maps of knowledge? Did perceptions on these matters undergo significant shifts by the end of the eighteenth century? This approach to the topic might seem paradoxical, because unlike earlier encyclopedic works, the major encyclopedias of the eighteenth century were alphabetically, rather than systematically, arranged. This format was in keeping with their titles (or in some cases subtitles): "*dictionaries* of arts and sciences." How, then, can they tell us anything about contemporary views on the organization of knowledge and the place of the various sciences within it? The answer, in part, is that editors regarded alphabetical arrangement as compatible with a classification of the sciences and even with a pedagogic order for reading the encyclopedia. In the prefaces to the leading publications, considerable rhetoric was invested in showing that an awareness of the relationships between the various fields of knowledge did inform the work in spite of its alphabetical listing of terms and concepts.[18]

Encyclopedic works of the Middle Ages and the Renaissance were topically, if not always systematically, arranged. Coherence could give way to miscellany, but rarely to alphabetical presentation. The order of their exposition of subjects was usually governed by some overarching pattern, such as the cosmological chain of being with the Divinity as its apex, the seven liberal arts, or the hierarchy of faculties in the university. Other schemes were also possible: in the fourteenth century, Domenicus Bandinus (c. 1335–1418) compiled an encyclopedic work, *Fons memorabilium universi,* which was divided into five parts to reflect the five wounds of Christ.[19] This power of theology was, of course, precisely what Enlightenment encyclopedists resisted, yet they did not dismiss the importance of classification, in spite of their departure from the traditional format of encyclopedias.

Some modern commentators are inclined to celebrate the advantages of strict alphabetical order more stridently than these eighteenth-century compilers. For example, Charles Porset, echoing the sentiment of Roland Barthes, writes, "As the zero degree of taxonomy, alphabetical order authorises all reading strategies; in this respect it could be considered an emblem of the

[18] See Richard Yeo, "Reading Encyclopedias: Science and the Organization of Knowledge in British Dictionaries of Arts and Sciences, 1730–1850," *Isis,* 82 (1991), 24–49.

[19] Lynn Thorndike, *A History of Magic and Experimental Science,* 8 vols. (New York: Columbia University Press, 1923–58), vol. 3, p. 560. For Renaissance works, see Neil Kenny, *The Palace of Secrets: Beroalde de Verville and Renaissance Conceptions of Knowledge* (Oxford: Clarendon Press, 1991).

Enlightenment."[20] Avoiding the hierarchies of systems, the alphabet is thus seen as egalitarian, reducing all subjects to the same level. In support of this view, we might add that, in principle, alphabetical arrangement allows indefinite expansion of content without the pressure to display connections or renegotiate categories. Commenting on advances during the Scientific Revolution, the economic historian Sir George Clark remarked that alphabetical ordering of information is not merely a matter of convenience and ready reference but rather reflects a situation "when knowledge is growing in many directions, and not in the framework of an accepted interpretation of the whole."[21] The early dictionaries of arts and sciences aimed to record and summarize data and doctrines from a wide range of intellectual territory – from Aristotelianism to Newtonianism, from gardening to heraldry. Given this, it is certainly fair to say that an alphabetical listing of short entries on terms avoided the need for synthesis, or the explicit placing of subjects in a philosophical taxonomy. Undoubtedly, Chambers and Diderot appreciated some of these advantages. Indeed Diderot's comment in the prospectus of 1750 to the *Encyclopédie* suggests that ease of access was an issue:

> We believe we have had good reason to follow alphabetical order in this work . . . If we treated each science separately and followed it with a discussion conforming to the order of ideas, rather than that of words, then the form of this work would have been even less convenient for the majority of our readers, who would have been able to find nothing without difficulty.[22]

Nevertheless, both Chambers's *Cyclopaedia* and the *Encyclopédie* carried charts of knowledge with supporting commentary, arguing that they allowed the careful reader to find the virtues of an encyclopedia within the pages of an alphabetical dictionary. "Former Lexicographers," wrote Chambers, "have not attempted any thing like Structure in their Works; nor seem to have been aware that a Dictionary was in some measure capable of the Advantages of a continued Discourse."[23] His diagrammatic display of the sciences was accompanied by a list of the terms belonging to each major subject so that, with cross-references, the reader could reconstitute a science that had been scattered alphabetically throughout the work. Similarly, in his *Preliminary Discourse* d'Alembert made it clear that the *Encyclopédie* was not just a dictionary:

> As an *Encyclopedia,* it is to set forth as well as possible the order and connection of the parts of human knowledge. As a *Reasoned Dictionary of the Sciences, Arts, and Trades,* it is to contain the general principles that form the basis of each science and each art, liberal or mechanical, and the most essential facts that make up the body and substance of each.[24]

[20] Charles Porset, cited by Broberg, "The Broken Circle," p. 49.
[21] George Clark, *Science and Social Welfare in the Age of Newton* (Oxford: Clarendon Press, 1937, 2nd ed. 1970), p. 143.
[22] Diderot, cited in Cynthia J. Koepp, "The Alphabetical Order: Work in Diderot's *Encyclopédie,*" in Steven Laurence Kaplan and Cynthia J. Koepp (eds.), *Work in France: Representations, Meaning, Organization, and Practice* (Ithaca, NY: Cornell University Press, 1986), pp. 229–57, at p. 237.
[23] Ephraim Chambers, *Cyclopaedia: or, an Universal Dictionary of Arts and Sciences,* 2 vols. (London: J. and J. Knapton, J. Darby, D. Midwinter et al., 1728), vol. 1, p. i.

Before discussing these charts or maps of knowledge it is important to recognize that, even without them, the new dictionaries of arts and sciences were informed by certain assumptions about the division of knowledge. For a start, the category "arts and sciences," although a large one, excluded history, biography, and geography. These subjects were the province of a separate genre of reference work: the historical dictionary. The leading examples were Louis Moreri's (1643–80) *Grand Dictionnaire Historique, ou mélange curieux de l'histoire sacrée et profane,* first published in Lyon in 1674, and issued in English translation in 1694 as *The Great Historical, Geographical and Poetical Dictionary;* and Pierre Bayle's (1647–1706) famous *Dictionnaire historique et critique* of 1697. These works – and others that followed them in the eighteenth century, such as the *Biographia Britannica* (1747–66; 2nd ed., 1778–93), were concerned with the lives of notable figures rather than with explications of the arts and sciences.[25] Another important feature of the dictionaries of arts and sciences is that although they broke down information into short entries on scientific and technical terms, they nevertheless operated with larger categories, such as natural history and natural philosophy, that entailed distinctive groupings of subjects. Furthermore, some of them appealed to a unity or circle of arts and sciences (as implied by the word "encyclopedia") and advised that a methodical course of study could be conducted on the basis of these single works.

This suggests that in spite of their affirmation of the quick and easy consultation allowed by alphabetical arrangement, these scientific dictionaries or encyclopedias deferred to contemporary convictions about the importance of system and order in learning. The pedagogic message carried by the influential works of Isaac Watts (1674–1748) is worth noticing here. His *Logick; or, the right use of reason* appeared in 1726, with a second edition in 1728, and a supplement to it was published in 1741 as *The Improvement of the Mind.* In a section of this second work dealing with the sciences, Watts announced

> The best way to learn any Science, is to begin with a regular System, or a short and plain Scheme of that Science. . . . Systems are necessary to give an entire and comprehensive View of the several Parts of any Science, which may have a mutual Influence toward the Explication or Proof of each other: Whereas if a Man deals always and only in Essays and Discourses on particular Parts of a Science, he will never obtain a distinct and just Idea of the whole.[26]

[24] D'Alembert, *Preliminary Discourse,* p. 4.
[25] For this distinction, see Richard Yeo, "Alphabetical Lives: Scientific Biography in Historical Dictionaries and Encyclopaedias," in Michael Shortland and Richard Yeo (eds.), *Telling Lives in Science: Essays on Scientific Biography* (Cambridge University Press, 1996), pp. 139–69.
[26] Isaac Watts, *The Improvement of the Mind,* 3rd ed. (London: T. Longman and J. Buckland, 1743), p. 316.

At least a nodding approval of this position is found in unexpected places. Periodicals, such as the *Universal Magazine of Knowledge and Pleasure,* that professed to cover the arts and sciences as well as other subjects avowed that their successive issues consolidated into a "whole body of arts and sciences." This is also apparent in the textbooks on natural and experimental philosophy by writers such as John Theophilus Desaguliers (1683–1744) and Benjamin Martin (1704–1782), which perhaps offer a closer comparison with the scientific dictionaries. In *The General Magazine of Arts and Sciences* (1755), Martin worked to insert his product in a competitive market. Other magazines, he argued, gave no coherent coverage of these subjects; what they did supply they did "only by Peace-meal [sic], in Bits and Scraps, disjointed and mangled, without Order or Connection, and therefore of no Use to any one."[27] Even if not treating the whole circle of sciences, Martin needed to rely on the notion that there were recognizable parts in order to sell his works, including those on the Newtonian sciences, as a course of study more methodical than that offered by periodicals and perhaps by the alphabetical encyclopedias that may have been his unmentioned target.

The eighteenth-century scientific dictionaries covered a wider range of subjects than particular scientific textbooks. The charts or maps of knowledge in Chambers and the *Encyclopédie* were meant to display this range and also to help the reader see relationships between subjects. Chambers's claim that the *Cyclopaedia* promoted coherent understanding of sciences, in spite of the fragmentation wrought by the alphabet, can be understood as deference to the views espoused by Watts. One might also note that as works needing subscriptions from members of the educated elite – scholars, gentleman, clerics – the dictionaries of arts and sciences were in no position to violate openly respected educational opinion, even though part of their content was knowledge that fell outside the university curriculum. In this context, some continuing obeisance to the systematic bent of the encyclopedic tradition made good commercial sense. But it is clear that the charts of knowledge were more than mere rhetoric: when the *Encyclopaedia Britannica* (from 1768) decided not to have one, it made a special point of attacking the assumptions behind such charts and their role in a modern encyclopedia. This was significant, too, because the French editors made so much of the English Lord Chancellor's "Division of Human Learning" outlined in *The Advancement of Learning* in 1605. Partly because of the influence of the *Encyclopédie,* the division of the sciences given by Bacon became commonplace during the second half of the century. It therefore requires some discussion here.

[27] *Universal Magazine of Knowledge and Pleasure,* 1 (1747), preface, p. ii; Benjamin Martin, *The General Magazine of Arts and Sciences* (London: W. Owen, 1755), p. iii. See also Martin, *A Course of Lectures in Natural and Experimental Philosophy* (Reading, 1743). On the popularization of science, see Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660–1750* (Cambridge University Press, 1992).

BACONIAN DIVISION OF THE SCIENCES

In "A Description of the Intellectual Globe" (written in 1612), Bacon said, "I adopt the division of human learning which corresponds to the three faculties of the understanding." By this he meant that different intellectual territories – History, Poetry, and Philosophy – depended, respectively, on Memory, Imagination, and Reason. History included natural history, geography, and political, ecclesiastical, and civil history, as well as the mechanical arts and crafts. Poetry covered the written and visual works of imagination, such as drama, painting, music, and sculpture. Philosophy, the largest group, contained "all arts and sciences," or, in Bacon's words, "whatever has been from the occurrence of individual objects collected and digested by the mind into general notions."[28]

This was a version of the classification given earlier in *The Advancement of Learning,* a work he later issued in Latin as *De Dignitate et Augmentis Scientarum* in 1623. The text of the Latin edition was reorganized on principles advocated by Petrus Ramus (1515–72), showing an argument proceeding from general to more specific propositions, and examples, by means of branching dichotomies. Thus, although Bacon did not include a chart, his division of the sciences was easily put into this form – as seen in many philosophical and pedagogic works of the sixteenth and seventeenth centuries.[29] Bacon's use of the tree metaphor also matched this approach, because it allowed him to say that the divisions between the sciences had a common point of origin and resembled "branches of a tree, that meet in a stem." This implied that there was a single "universal science," or *Philosophia Prima,* from which all other sciences derived. But this reference to unity was followed by a set of divisions. The Sciences were classed under Natural Philosophy and had two parts: the "inquisition of causes, and the production of effects." The former, or natural sciences, then divided into Physics and Metaphysic. Physics dealt with what was "inherent in matter, and therefore transitory"; Metaphysic with that "which is abstracted and fixed." Or, to put this in Aristotelian terms, Physics concerned efficient causes; Metaphysic formal and final causes.[30] Bacon also introduced the term "Mixed Mathematics" to denote subjects such as optics,

[28] Francis Bacon, "A Description of the Intellectual Globe," in *The Works of Francis Bacon,* collected and edited by James Spedding, Robert Leslie Ellis, and Douglas Denon Heath, 14 vols. (London: Longman, 1857–74; reprinted Stuttgart-Bad Cannstatt: F. Frommann Verlag, 1961–3), vol. 5, pp. 503–4.

[29] See Graham Rees (assisted by Christopher Upton), *Francis Bacon's Natural Philosophy: A New Source* (Chalfont St. Giles: British Society for the History of Science, 1984), p. 19, n. 45; Joseph S. Freedman, "Diffusion of the Writings of Petrus Ramus in Central Europe, c. 1570- c. 1630," *Renaissance Quarterly,* 46 (1993), 98–152, especially 103–5. I thank Marta Fattori and Graham Rees for advice (personal communications) about the absence of illustrations of the division of knowledge in editions of *De Augmentis* before the mid-eighteenth century.

[30] Bacon, *Advancement of Learning,* in *Works,* vol. 3, pp. 346, 351–4. For the version in *De Augmentis, Works,* vol. 4, p. 337.

astronomy, harmonics, and mechanics, as well as cosmography, music, and architecture, thus expanding Aristotle's category of "*scientia media.*"[31]

Bacon's scheme was novel, and deliberately so, because it departed from the traditional divisions of the sciences by subject area. Instead, he classified in terms of the mental faculty operating in the acquisition of three different branches of knowledge, yet still maintained that there were links between all branches of learning. His "Division of Human Learning" was a reference point for classifications of knowledge during the eighteenth century – not because it established a fixed and agreed system, but rather because it made distinctions while at the same time setting off debates about them.

Within what we now call science, Bacon drew a major dichotomy between natural philosophy and natural history. The former, located under the faculty of Reason and part of philosophy, embraced all the mathematical and physical sciences – disciplines that eighteenth-century writers recognized as the Newtonian sciences. In contrast, natural history belonged to Memory and was charged with producing adequate descriptions (histories), collections and taxonomies of minerals, plants, animals, and, significantly, accounts of the manual crafts and machines. Yet, at the same time, Bacon challenged the subordination of natural history to natural philosophy – that is, in the sense of mere facts compared with universals. He contended that the particular observations and "facts" of natural history were more secure and certain than many of the so-called demonstrations and axioms of the rival systems of natural philosophy on display in his own day.[32] Bacon's work thus became the framework for debates about the relations between the sciences in which some of his own divisions were adopted more rigidly than he intended before being abandoned by the end of the century. We should keep this in mind while discussing the classification of sciences in the major encyclopedias of the period.

HARRIS'S *LEXICON TECHNICUM*

The examples of Harris, Chambers, and Diderot and d'Alembert offer the chance to consider how classification of the sciences worked in three significant dictionaries of arts and sciences. In all three, alphabetical arrangement displaced pedagogic order, but each acknowledged the need for consideration of the larger subjects, which they reduced to numerous short entries (and in some cases, longer articles) on terms. However, the issues of classification and its display in the form of charts were handled differently in these three works.

[31] Bacon, *Works*, vol. 3, 360–1; Gary Brown, "The Evolution of the Term 'Mixed Mathematics,'" *Journal of the History of Ideas*, 52 (1991), 81–102, at 82–3; Sachiko Kusukawa, "Bacon's Classification of Knowledge," in Markku Peltonen (ed.), *The Cambridge Companion to Bacon* (Cambridge University Press, 1996), pp. 47–74, at pp. 49, 60.

[32] Lorraine Daston, "Baconian Facts, Academic Civility, and the Prehistory of Objectivity," *Annals of Scholarship*, 8 (1991), 337–63; Dear, *Discipline and Experience*, chap. 1.

Harris did not have a chart or map; Chambers used a chart of knowledge based on the branching dichotomies similar to those found in scholastic treatises and in the Ramist pedagogic texts from the sixteenth century; Diderot and d'Alembert revived Bacon's tripartite division of sciences by reference to mental faculty. Did these compilers agree on the main divisions within the sciences? How did they use charts of knowledge to indicate the relations between sciences?

Harris declared that the *Lexicon Technicum* was "a Dictionary not only of bare *Words* but *Things*," or an explication of how "*Technical* Words" were used in the "*Liberal Sciences*" and some of the practical arts associated with them, such as navigation, ship building, the construction of mathematical and geometrical instruments, and also air pumps. A review in the *Philosophical Transactions* of the Royal Society of London endorsed this description, saying that "the design of this Dictionary is different from that of most others," and then, almost in Harris's own words, explained that it gave not only the "terms used in every Art and Science, but likewise the Arts and Sciences themselves." In the first volume Harris apologized for not being able to supply "at the End of the Book, a particular *Alphabet* for each *Art* and *Science* by it self."[33] But when the next volume appeared in 1710 (again covering the whole alphabet, but with new, and supplementary, entries) this list, accounting for the contents of both volumes, was appended.

Although he certainly did not present this "Index" as a grand scheme of classification, it did cluster the particular terms treated in the work under what Harris presumably regarded as recognizable subjects. Since there was no pagination in the *Lexicon*, this "Alphabetical Index" did not give page (or even volume) references to particular topics; rather, it listed the terms treated in the dictionary under twenty headings (or "Heads," in contemporary usage). This format allowed Harris to display a large number of subjects without having to place them in a hierarchy or delineate any relations between them. It also avoided the problem of naming some as arts and others as sciences. The list began with "Navigation" and ended with "Astronomy" and included headings for "Mathematical and Philosophical Instruments," "Fortification," "Dialling," "Anatomy," "Law," and "Heraldry." Within some of the headings, Harris's grouping of terms has a rough-and-ready look about it: some terms such as "Acids," "Earth," "Stones," and "Vegetables" appear under more than one heading. Given this, it is prudent not to exaggerate the evidence it provides; but the fact that it was done at all is revealing, since it suggests that Harris felt unable to let the alphabet stand without comment. As such, this Index offers some indication of how a dictionary maker and member of the Royal Society perceived the major areas of science.

[33] "An Account of a Book," *Philosophical Transactions*, vol. 24, no. 292, 1704, 1699–1702, at 1699; John Harris, *Lexicon Technicum; or an Universal Dictionary of Arts and Sciences* (London: Brown, Goodwin et al., 1704), vol. 1, "The Preface," no pagination.

There were three main headings covering natural knowledge: (1) "Natural Philosophy and Physicks"; (2) "Chymystry"; (3) "Botany, Natural History and Meteorology." Two of these – natural philosophy and natural history – were mentioned in the Introduction as large categories under which some new material had been incorporated in the second volume. There were also separate headings for "Mechanicks, Staticks," "Opticks and Perspective," and "Astronomy and the Doctrine of the Spheres." In part, this was because the *Lexicon* had so many entries from these sciences, reflecting Harris's interest – he was known as "Technical Harris" – but also because of their well-established status as disciplines of mixed mathematics. But it is clear from the definition of "Natural Philosophy" in the work itself that these subjects fell under that category, whereas "Geometry" and "Arithmetic and Algebra" – pure mathematics – did not. The contrast between the sciences under "Natural Philosophy" and those of "Natural History" (as described in the entry in Volume Two) was clear. The former were part of Newtonian philosophy, whereas the latter were mainly descriptive histories of the natural world – of earth, water, air, metals, minerals, fossils, and the beasts, birds, and fishes that inhabit the globe. The entry for natural history thus defined it as Bacon did, although in the Introduction to the second volume Harris advertised that he now also included schemes by which plants and animals "are ranged and distributed into their proper Orders."[34]

The only other physical science with a heading of its own in the *Lexicon* is chemistry. This reflected its position as a subject in which there were chairs at universities and specialist textbooks. Given Harris's emphasis on the physico-mathematical sciences it is not surprising that his treatment of this subject was fairly restricted, largely amounting to a definition or description of the names of chemical substances and techniques of analysis, collated under "Chymystry" in the Index and drawn from specialist chemical dictionaries cited in the Preface. This matches the humble definition of the subject, given in the first volume, as an "Art" aiming to "separate the Purer Parts of any mix'd Body from the more Gross and Impure."

CHAMBERS'S *CYCLOPAEDIA*

In his *Cyclopaedia* Chambers acknowledged Harris but claimed to go beyond previous dictionaries of arts and sciences by providing the option of a systematic reading of an alphabetical dictionary. Significantly, to allow such a methodical use of its content, he offered a diagrammatic chart of knowledge that portrayed the relationships of the sciences.[35] Chambers referred to this

[34] Harris, *Lexicon Technicum* (London: Brown, Goodwin et al., 1710), vol. 2, "Introduction," no pagination. The "Alphabetical Index" is at the end of this volume.

[35] On one context for this, see Richard Yeo, "Ephraim Chambers's *Cyclopaedia* and the Tradition of Commonplaces," *Journal of the History of Ideas*, 57 (1996), 157–75.

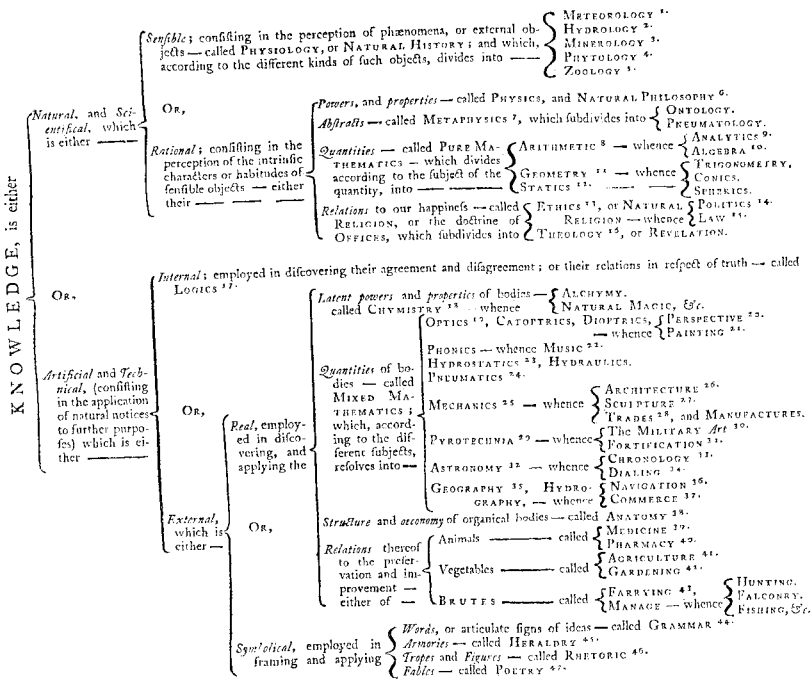

Figure 10.1 The "View of Knowledge" in the Preface of Chambers's *Cyclopaedia* (London, 1728). This appeared in all editions. The Wellcome Institute Library, London.

illustration, not as tree or map, but as a "View of Knowledge." Knowledge was categorized as either "Natural and Scientifical" or "Artificial and Technical" and then separated into further subdivisions, as in "method of dichotomies" of the Ramist kind (see Figure 10.1). After the first division, scientific (versus technical) knowledge of nature was divided into "sensible" or "rational," distinguishing between, say, meteorology and geometry. On the other hand, knowledge acquired for technical purposes was classed as either "internal" (logic) or, more frequently, "external," such as all the arts and crafts but also sciences such as optics, hydrostatics, pneumatics, mechanics, and chemistry. Clearly, then, this is not a simple contrast between arts and sciences, a distinction Chambers confessed to be unsure about. Indeed, the chart juxtaposes certain arts with particular branches of the mixed sciences: thus, Mechanics is linked with Architecture, Sculpture, Trades and Manufactures; Optics with Painting and Perspective; Astronomy with Chronology and Dialling. Chambers said that "the precise notion of an Art and Science, and their just, adequate Distinction, are not yet well fixed."[36]

[36] Chambers, *Cyclopaedia*, vol. 1, pp. i–v, for discussion of the chart. On the art/science relationship,

What relationships between the various sciences did this "View" convey? Chambers did not follow Bacon's classification by mental faculties, which allocated both the mechanical arts and natural history to Memory. Admittedly, in the Preface he did speak of different sciences deriving from the senses, reason, or imagination – thus apparently referring to mental faculties – but his classification is not a psychological one; in fact, he appears to have regarded the major divisions of arts and sciences as only conventional labels.[37] Moreover, his classification by dichotomies placed *both* natural history and natural philosophy on the "scientifical" branch, unexpectedly separating natural philosophy from the disciplines of mixed mathematics, which are located on the "artificial" or "technical" branch. Nevertheless, like Bacon and Harris, Chambers distinguished between the two large categories of natural history and natural philosophy: the former as "Sensible" and the latter as "Rational." And in the body of the work he made it clear that natural philosophy, or the version of it pursued by Newton – namely, "experimental philosophy" – was "scientific" in a way that studies in natural history were not: "In Effect, *Experiments*, within these 50 or 60 Years, are come into such Vogue, that nothing will pass in Philosophy, but what is founded on Experiment, etc. So that the new Philosophy is almost altogether *Experimental*."[38]

In both Harris and Chambers, chemistry is the third man, neither conclusively under natural history nor conclusively under natural philosophy. Chambers's entry on this subject is more detailed than Harris's, describing chemistry as an art of analysis: "separating the several Substances whereof mix'd Bodies are compos'd." Chemistry was still defined as an art, and not a science, in Samuel Johnson's *Dictionary* of 1755 which, like Chambers, cited the definition given by Hermann Boerhaave (1668–1738), head of the medical faculty at the university of Leiden and professor of chemistry there from 1718 to 1729.[39] (Chambers and Peter Shaw (1694–1763) translated and published *A New Method of Chemistry* in 1727, based on Boerhaave's lectures.) But even though it was clearly recognized as a distinct subject, Harris and Chambers were unsure about its relation to the two large categories that informed their classification. This is highlighted by the fact that the list of terms under "Natural Philosophy" in the Index of the *Lexicon* included terms that, later in the century, would fall uncontentiously under chemistry – terms such as "Acidity," "Air," "Condensation," "Fermentation," "Phosphorus," "Spring of the Air," "Sulphur" and "Vapours." A few of these also occur under the heading for "Chymystry," but their presence in two places requires comment.

see the long discussion in the Preface at vol. 1, pp. vii–xvi, and "Science," vol. 2 (no pagination in body of the work).

37 Ibid., vol. 1, p. ii.; also Yeo, "Reading Encyclopedias," pp. 28–9; Fisher, "The Classification of the Sciences," p. 861.

38 Chambers, *Cyclopaedia*, vol. 1, "Experimental Philosophy."

39 Chambers, *Cyclopaedia*, "Chymistry," vol. 1. See J. R. Partington, "Chemistry through the Eighteenth Century," in Alan Ferguson (ed.), *Natural Philosophy Through the 18th Century and Allied Topics* (London: Taylor and Francis, 1972), pp. 47–66 at p. 48.

In both these scientific dictionaries, the category of natural philosophy (or "physicks") operates in a different way from the most advanced disciplines usually accepted as part of it. In the *Lexicon* (Volume Two), the entry for "Physicks," or natural philosophy, confirms that the sciences of astronomy and optics, most illustriously pursued by Newton, certainly belong to this category. The entry is mainly a list of books that "will give the Reader a true and useful knowledge of Nature"; it begins with the *Principia*. But this bibliography is not confined to the so called Newtonian sciences, and it includes John Woodward (1665–1728) and William Whiston (1667–1752) on the history and theory of the earth. The heading of natural philosophy in the Index also goes beyond the mixed mathematical sciences in its list of terms – a curious catalog including not only the chemical terms mentioned above, but also some that seem to belong elsewhere, such as "Animals," "Earth," "Stones," "Vegetables," "Zoography." Some of these terms, as we might expect, also occur under "Botany, Natural History." Similarly, in his explication of "Physics, or Natural Philosophy" in the large footnotes accompanying the chart, Chambers does not mention the terms from the most obvious sciences – namely, those of mixed mathematics – because he gives them their own headings. Rather, this note shows the province of natural philosophy by listing terms pertaining to the "Powers" and "Properties" of nature such as attraction, elasticity, cohesion, electricity, and magnetism. Thus, natural philosophy functions as a general label for inquiries into the principles and causes of natural phenomena as well as a heading for a number of recognized disciplines. But it was not confined to the "classical sciences," as defined by Kuhn. Instead, some of what Kuhn called Baconian sciences were seen as legitimate, if undeveloped, parts of natural philosophy and its search for causes of phenomena in nature. This is why the German philosopher Christian Wolff, in *Preliminary Discourse on Philosophy in General* (1728), could consider a subject such as meteorology (classed as natural history in the English works) as natural philosophy, provided that it searched for causes of phenomena such as rain, rainbows, and lightning. Other forces and powers of nature, such as electricity and magnetism, thus came under this heading even though they had not been successfully explained on mechanical principles.[40] Chemistry, in particular, was seen as pressing its claim to be a science of causes and powers. Harris included the term "Acids" under natural philosophy and, in the Introduction to the volume of 1710, advertised the insertion of an unpublished paper, "De Acido," by Newton. He supplied a translation of this, noting how it made good Newton's suggestion in the *Optics* that attractive forces between small particles of matter could be understood in terms of laws of matter and motion.

40 Christian Wolff, *Preliminary Discourse on Philosophy in General*, translated, with an introduction and notes, by Richard J. Blackwell (New York: Bobbs-Merrill, 1963), p. 42. See also Patricia Fara, *Sympathetic Attractions: Magnetic Practices, Beliefs, and Symbolism in Eighteenth-Century England* (Princeton, NJ: Princeton University Press, 1996), pp. 142–3.

Indeed, the last sentence of Chambers's entry gave an optimistic gloss on this story: "Dr. Friend [sic] has reduc'd *Chymistry* to *Newtonianism*, and accounted for the Reasons of the Operations on Mechanical Principles."[41]

It could be said that the main concern of Harris and Chambers was not the sophisticated mapping of the relation *between* sciences but rather was the listing of cognate terms under certain sciences. Chambers built on Harris's Index by showing the arts and sciences on a chart, but the main contribution of his work was the use of cross-references between the terms of *each* science. Nevertheless, both compilers assumed a larger classification as the foundation of their comments on the sciences. Whereas Harris's *Lexicon* had no map or chart and Chambers did not use Bacon's division by mental faculty, these two English dictionaries were informed by the contrast between natural philosophy and natural history. In fact, they may have adopted it more completely than Bacon, who always regarded the data of natural history as the "primary matter" on which the causal inquiries of natural philosophy were built.[42]

THE *ENCYCLOPÉDIE*

Diderot and d'Alembert acknowledged that Chambers had sought to sketch the relationships between the various sciences; but they claimed that this needed more attention and made much of rediscovering Bacon's contribution. The famous frontispiece of the *Encyclopédie* by Charles-Nicolas Cochin (1715–1790) was not prepared until 1764, but it expressed the message of both the prospectus (1750) and *Preliminary Discourse* (1751). It shows three figures. Reason, the most prominent, is lifting the veil from Truth (with the help of Philosophy); Memory and Imagination, each accompanied by its respective sciences and arts, are situated, respectively, to the right and left of Truth.[43] At the end of the *Preliminary Discourse*, the diagram (see Figure 10.2) depicting the Baconian system – which the editors usually referred to as an "encyclopedic tree" – made it clear that Reason controlled the largest number of arts and sciences. This point was graphically underscored later in the engraving of a tree of knowledge in the frontispiece to volume one of the supplementary index in 1780. This was a large folding sheet (39 by 24 inches) with tree and branches engraved by Robert Benard.[44] Here the trunk of Reason

[41] Harris, *Lexicon*, 1710, vol. 2, Introduction, for the paper by Newton; Chambers, *Cyclopaedia*, "Chymistry," vol. 1. This is a reference to the Oxford academic John Freind. On the point that chemistry was a "core subject at a time when physics [in the modern sense] had hardly achieved that status," see Maurice Crosland, *In the Shadow of Lavoisier:* The Annales de Chemie *and the Establishment of a New Science* (Oxford: British Society for the History of Science, 1994), p. 156.

[42] Bacon, *Works*, vol. 3, p. 356; Kusukawa, "Bacon's Classification of Knowledge," p. 53.

[43] Georges May, "Observations on an Allegory: The Frontispiece of the *Encyclopédie*," *Diderot Studies*, 16 (1973), 159–74, at 162–4.

[44] For the tree image, see d'Alembert, *Preliminary Discourse*, p. 159; but he also used a "map" metaphor

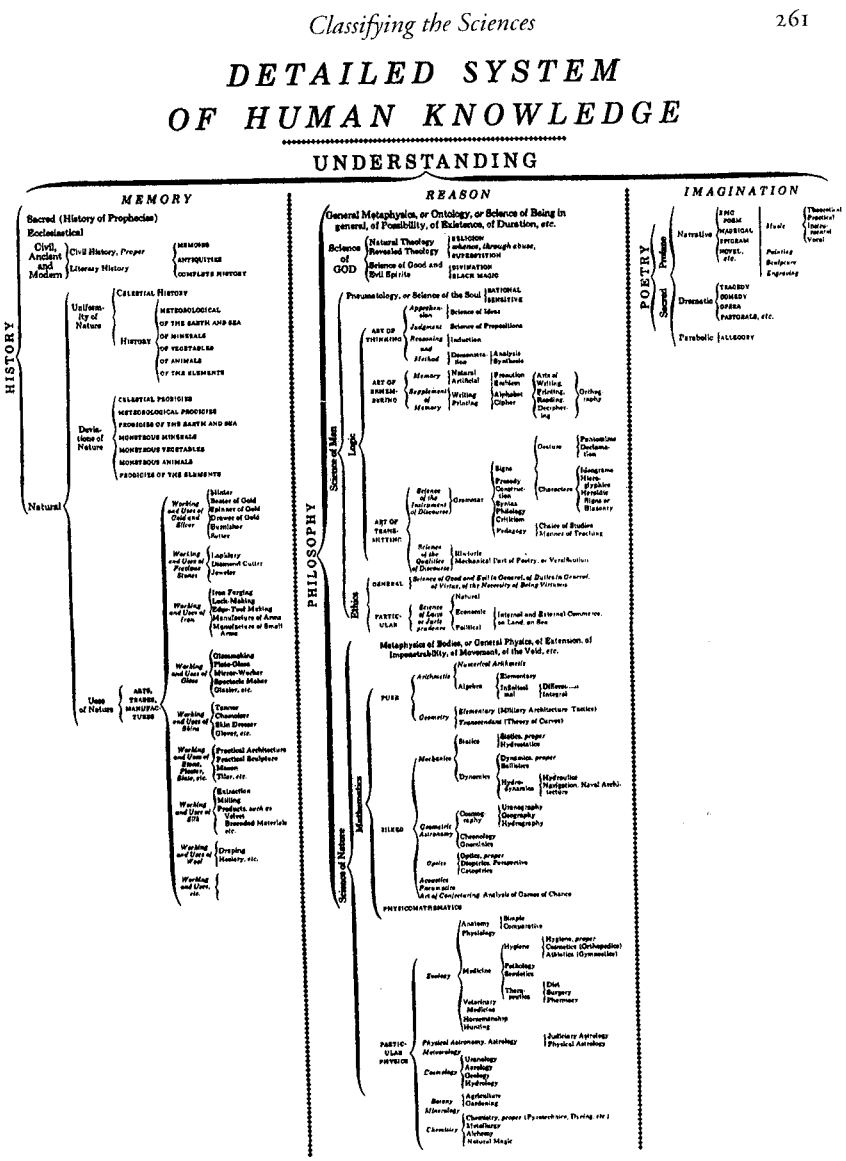

Figure 10.2 The classification of knowledge, influenced by Bacon, given in d'Alembert's *Preliminary Discourse* (1751). Source: *Preliminary Discourse to the Encyclopedia of Diderot*, translated by Richard N. Schwab, with the collaboration of Walter E. Rex; with an introduction and notes by Richard N. Schwab (Chicago: University of Chicago Press, 1995), pp. 144–5.

overwhelms the two main branches of Memory and Imagination; in fact, the sub-branch for Mathematics, shooting off from the main trunk of Reason, is itself more luxuriant than either of these.

Diderot and d'Alembert did not passively repeat Bacon's classification; they transformed his concept of Philosophy – the foundational trunk of all the sciences – into the Enlightenment torch of Reason. Robert Darnton suggests that Diderot and d'Alembert took "enormous risks" in undoing "the old order of knowledge" in this way: that is, by replacing Theology with Reason or Philosophy and excluding all knowledge without an empirical base, rather than allowing a separate tree, as Bacon did, for Divine Knowledge.[45] But for the purpose of this chapter, there is another issue: what did their use of the Baconian scheme entail for the way the *sciences* were classified? Apart from the restoration of the three mental faculties, did their chart of knowledge present a different arrangement of the sciences from that of Chambers or Harris?

The French editors stressed that "all encyclopedic trees necessarily resemble one another" in terms of the kinds of arts and sciences they included; the differences concerned the order and arrangement of the various branches. As d'Alembert put it, "One finds virtually the same names of the sciences in the tree of Chambers as in ours; yet nothing could be more different."[46] This is an admission that, like Harris and Chambers, they also worked with the categories of natural history and natural philosophy. The former, under Memory (where Bacon put it), included descriptions of the uniformities and deviations of nature together with the uses of nature exemplified in all the practical arts. Natural philosophy was not named as such, but all the sciences that Harris and Chambers placed in this category were now under "Science of Nature," which belonged to Philosophy and, of course, to the faculty of Reason. But Diderot and d'Alembert also began to undermine the earlier qualitative distinction between these two large categories. The membership of "Particular Physics" – the main grouping of physical sciences (apart from mixed mathematics) – included subjects such as zoology, meteorology, botany, mineralogy, and geology. Earlier mapmakers, such as Chambers, grouped these under Bacon's heading of natural history. Significantly, then, these subjects were now released from the lowly domain of Memory. Instead, they joined chemistry, which was also now indisputably a member of these sciences of nature, although it was also singled out as "the imitator and rival of nature," and the article on "natural history" declared that chemistry started where

(pp. 47–50). On the engraving, see Robert Shackleton, "The Encyclopaedic Spirit," in Paul J. Korshin and Robert R. Allen (eds.), *Greene Centennial Studies: Essays Presented to Donald Greene* (Charlottesville: University of Virginia Press, 1984), pp. 377–90, at pp. 386–7.

[45] Robert Darnton, "Philosophers Trim the Tree of Knowledge," in *The Great Cat Massacre and Other Essays in French Cultural History* (London: Penguin, 1985), pp. 185–207, at p. 187. See also Cassirer, *Philosophy of Enlightenment*, p. vii.

[46] D'Alembert, *Preliminary Discourse*, p. 159; see also pp. 151–5.

natural history ends.[47] Thus, under "Reason" in the *Encyclopédie*, there was now a continuum from pure and mixed mathematics to the experimental and observational sciences rather than a qualitative break between natural philosophy and natural history.

At one level, this reflected the rising status of the natural history disciplines. Diderot was an active defender of the organic sciences against the authority of mathematics, a campaign also assisted by Buffon in the introductory Discourse to his *Histoire Naturelle* (1749), where he insisted that the natural history disciplines must generalize. In 1777, Kant distinguished between *Naturbeschreibung* (description) and *Naturgeschichte* (historical development), thus opening the possibility of a study of *historical* causation in nature – thus, still distinct from natural philosophy but not by being limited to description and taxonomy.[48] In Britain, the shift to this more theoretical agenda for natural history was slower to appear. The *Encyclopaedia Britannica* maintained the distinction between natural history and natural philosophy, stating that only the latter had "universal laws of nature" as its province. This position continued in the third edition in the short entry for "Natural Philosophy"; but there was also the acknowledgment here that the data provided by natural history was the basis for more theoretical and causal speculations. James Hutton (1726–1797) put this more positively than some of his fellow Scots in 1794, arguing that "natural history and natural philosophy should proceed together with mutual advantage."[49] At another level, however, this more relaxed attitude to earlier distinctions between these two large categories reflected the demise of systematic classification of the sciences in encyclopedias of the late eighteenth century.

THE DEMISE OF MAPS OF KNOWLEDGE IN ENCYCLOPEDIAS

In 1778, in the first volume of the *Deutsche Enzyclopädie*, its editors attacked Diderot and d'Alembert for their fixation on general principles and "the overgrown forest of a connected system" that they sought to convey. By way of contrast, this German work offered to "leave both the effort of frantically looking for a connection among materials and sciences that are barely or not at all connected and the honor of the task, to the compilers of the French

[47] Ibid., p. 155; "Histoire Naturelle," in *Encyclopédie; ou Dictionnaire Raisonne des Sciences, des Arts, et des Metiers* (Paris: Briasson et al., 1751–65), vol. 8, pp. 225–30, at p. 228.

[48] Cited in John Lyon and Phillip Sloan (eds.), *From Natural History to the History of Nature* (Notre Dame, IN: University of Notre Dame Press, 1981), p. 2. For Buffon' s "Initial Discourse," see pp. 97–128.

[49] "Physics," *Encyclopaedia Britannica*, 2nd ed. (Edinburgh: Bell and Macfarquhar, 1778–84), vol. 7, p. 6171; "Natural Philosophy," *Encyclopaedia Britannica*, 3rd ed., 18 vols. (Edinburgh: Bell and Macfarquhar, 1788–97), vol. 12, p. 670; James Hutton, *An Investigation of Principles of Knowledge* (Edinburgh: A. Strahan, 1794), vol. 3, p. 38.

Encyclopédie."[50] As it turned out, this restraint did not help the editors of this encyclopedia complete their project: it terminated at the letter *K* in 1804. But the doubts voiced here about classification of knowledge were already apparent in the *Encyclopédie.* At the end of the *Preliminary Discourse,* d'Alembert confessed that "our readers" might not be much interested in disquisitions on trees of knowledge. Although the discussion of Bacon's scheme undoubtedly brought the issue of classifying sciences to a wider public, the mixed metaphors of maps, charts, and trees that pervade the text may have contributed to doubts about this exercise. In spite of their comments on the importance of such classification, Diderot and d'Alembert made it clear that they regarded all systems of this kind as arbitrary and relative. The entry on "Philosophie" (published in 1765) referred to the non-Baconian system of Christian Wolff.[51]

With the publication of the *Encyclopaedia Britannica* between 1768 and 1771 there was a major encyclopedia with no map of knowledge.[52] The first two editions criticized Chambers's approach for fragmenting sciences into short entries on terms and proclaimed their "new plan": larger treatises on the major subjects, although still in alphabetical order, and short entries as satellites to the long treatises. By the third edition, starting in 1788, there was a frontal assault on the notion that a chart or map could assist the reader in reconstituting sciences that had been scattered by the alphabet. Acknowledging Chambers's efforts, the Scottish editors declared that his work "was still a book of shreds and patches, rather than a scientific dictionary of arts and sciences." Indeed, they went further, invoking the authority of Thomas Reid (1710–1796) to spurn all systematic classification of the sciences as presumptuous, as trying to "contract the whole furniture of the human mind in to the compass of a nutshell." They even included a copy of Chambers's chart, introduced by this note: "To be convinced of the truth of this assertion, one needs but cast his eye over the author's table of arrangement."[53] Significantly, the mere sight of this chart is taken here as an argument against it, and the *Cyclopaedia* is branded as a miscellany in spite of its attempt to provide a path through the various sciences. By the last quarter of the century, most encyclopedias had abdicated responsibility for any systematic classification of the sciences they covered. The emphasis was now on coherence at the level of

[50] Willi Goetschel, Catriona MacLeod, and Emery Snyder, "The Deutsche Encyclopädie and Encyclopedism in Eighteenth-Century Germany," in Clorinda Donato and Robert M. Maniquis (eds.), *The Encyclopédie and the Age of Revolution* (Boston: G. K. Hall, 1992), pp. 55–61, at p. 58.

[51] D'Alembert, *Preliminary Discourse,* p. 164; Tonelli, "The Problem of Classification," p. 264 referring to "Philosophie," in the *Encyclopédie,* vol. 12, pp. 509–15. See McCrae, *The Problem of Unity,* pp. 8, 109–122, on the ambiguous attitude of d'Alembert and Diderot to the classification of the sciences.

[52] See Yeo, "Reading Encyclopaedias," pp. 29–34. Some minor English works emulated the *Encyclopédie* by carrying a Baconian map of knowledge; but their prefaces stressed the difficulty of defending any single version of such grand taxonomies. See, for example, [John Barrow], *A Supplement to the New and Universal Dictionary* (London: printed for the Proprietors, 1754), preface, pp. 9, 14. The first volume of 1751 had a "Synopsis" of arts and sciences "arranged in their proper order," but no chart.

[53] *Encyclopaedia Britannica,* 3rd ed., 1788–97, vol. 1, pp. vii–viii.

disciplines, expounded in extensive treatises. Indeed, from 1782 the *Encyclopédie Methodique* (the successor to the *Encyclopédie*) was really a dictionary of dictionaries, so that, in the words of a reviewer, "every science will have its dictionary, or system, apart."[54] The *Britannica* continued this format, devoting large treatises to the major disciplines but placing them alphabetically within its volumes.

Soon after the decision to supply large treatises on each science there was recruitment of expert contributors. The third edition of the *Britannica* proudly announced its use of respected writers for various branches of science, a feature that became even more prominent in the *Supplement* of 1801, when John Robison (1739–1805) did almost all the physical sciences and Thomas Thomson (1773–1852) took over chemistry. This was linked with the need to keep abreast of the most recent advances. Thomson explained what this meant in the case of chemistry:

> So rapid has this progress been, that though the article Chemistry in the *Encyclopaedia Britannica* was written only about ten years ago, the language and reasoning of chemistry have been so greatly improved, and the number of facts have accumulated so much, that we find ourselves under the necessity of tracing over again the very elements of the science.[55]

The treatises on disciplines, written by experts, became more specialized: the cross-references from these articles were mainly to shorter entries on the cognate terms of a particular science, and not to other sciences. The boundaries between disciplines were often sharpened as contributors sought to codify the agreed data and principles of their own subject and as editors worked to allocate subject matter to different contributors.[56] In the case of topics such as heat, magnetism, and electricity, this could lead to artificially clean demarcations. But this drawing of boundaries did not renew consideration of the relations between various sciences under a broader natural philosophy. In fact, the entries on this term (and on natural history) were usually short, giving a historical gloss on its earlier meaning but then referring to the separate articles on the physical sciences, such as mechanics, hydrostatics, optics, and astronomy, and the new subjects forming around studies of magnetism and electricity. By the late eighteenth century, encyclopedias were also carefully registering the identity of new organic sciences that did not fit the old category of natural history. The *Britannica* explained that physiology "is a Greek word, which, in strict etymology, signifies that which discourses of

[54] "Proposals for Publishing a Methodical Cyclopaedia," *Monthly Review,* 66 (1782), pp. 514–18, at p. 514.

[55] Thomas Thomson, "Chemistry," in George Gleig (ed.), *Supplement to the Third Edition of the Encyclopaedia Britannica* (Edinburgh: T. Bonar, 1801), vol. 1, p. 210. On the use of specialists, see vol. 1, p. v.

[56] Yeo, "Reading Encyclopedias," pp. 43–7; for the *Encyclopédie Methodique,* see Robert Darnton, *The Business of Enlightenment: A Publishing History of the Encyclopédie, 1775–1800* (Cambridge, MA: Harvard University Press, 1979), pp. 422, 451.

nature: but in its common use, it is restricted to that branch of physical science which treats of the different functions and properties of living bodies." This was a definite dismissal of the more general sense this term had earlier in the century, when it was still given by Harris, Chambers, and Martin as equivalent to physics or natural philosophy. It was now explicitly defined as a specialist discipline with a distinct identity: "We choose here to mark precisely the bounds of physiology, because we have always been led to imagine that it would be extremely fortunate for science that all its divisions were accurately defined, that each were restricted in its own sphere."[57]

CONCLUSION

With the collapse of the main categories of natural history and natural philosophy – which had been central to most classification of the sciences – encyclopedias abandoned any attempt to show how the various scientific subjects related to one another. The "circle of sciences" was no longer a path that readers were expected to follow. This did not mean that distinctions between the sciences became unimportant: as the example of physiology suggests, scientists were possibly becoming more concerned with marking out the boundaries of their specialist disciplines than earlier natural philosophers had been. Indeed, specialization stimulated the elaborate classification schemes of Comte, Ampère, Spencer, and others in the nineteenth century. But at the level of the public communication of science in encyclopedias, the emphasis on coherence was at the level of increasingly autonomous disciplines rather than on the position of these on a map or chart of sciences. It is a telling point that when the *Britannica* used the word "systems" on its title page, it referred to its treatises on particular sciences, and not to grand doctrines of natural philosophy or to the classification schemes that once prefaced earlier encyclopedias.

57 "Natural Philosophy," *Encyclopaedia Britannica*, 3rd ed., vol. 12, pp. 670–1; "Physiology," vol. 14, p. 665.

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1 James A. Weisheipl, "The Nature, Scope and
(ed.), *Science in the Middle Ages* (Chicago: Uni
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