A BRIEF INTRODUCTION TO WAYS OF KNOWING AND WAYS OF WORKING

John V. Pickstone

CHSTM, University of Manchester

The five invited papers in this collection both use and test the Ways of Knowing approach for a range of topics which spans from chemistry around 1800 to molecular biology now, and from classical bacteriology to classifications used in cancer hospitals. I have added two sections. At the end of the volume, I reflect on the papers, and then extend the discussion to further aspects of the WoK method and its potential uses. But additionally, in this Introduction, I have tried to summarize my general approach in the hope that the volume can be used more easily by readers who are new to the WoK project. To a first approximation, I here summarize material presented in my book of 2000/1 and my *Isis* paper of 2007; I have tried to simplify as much as possible, leaving the elaborations and qualifications to the Afterwords.¹

The basic idea of the WoK approach is that the multiple configurations of knowledge and working practices seen in the general area of science, technology and medicine (STM), both now and across time, can be analysed as ‘compounds’ — as made up of ‘elementary’ ways of knowing and working. I have tried to characterize several ‘elementary’ types of ways of knowing (WoK) and of ways of working (WoW). I have further suggested, in 2007, that each WoK is associated with a WoW, and that each of the pairs might be also be seen as constituting a type of ‘working knowledge’; but in most of this presentation I will use WoKs and WoWs separately. These WoKs and WoWs are seen as developing, cumulating, and ‘nesting’, over time; the later ones involve the earlier, but the earlier may continue independently, as we shall see.

To avoid a common misunderstanding, I stress here that WoKs and WoWs are used like elements in modern chemistry and not as taxonomic boxes into which instances of STM are to be placed, or forced. In that respect my approach differs notably (though not completely) from the listings of styles as given by Alistair Crombie and Ian Hacking — which are usually read as taxonomic.² Hacking, it is true suggests that his styles can be combined, though he did not pursue this aspect. But if, by contrast, one looks for types of knowing and working which are interwoven in various ways, then the combinatorial possibilities are enormous. And since the analysis of complex cognitive and social configurations can be pursued to any level of detail, the method is not reductive in the usual objectionable senses.

Hopefully indeed, the subtleties evident in the best recent historical and sociological analyses of STM can be modelled in ways which do justice to the cases, but which are also sufficiently systematic to facilitate multiple comparisons — including the transfer of historiographical findings between different fields of HSTM. Since these elements are ideal types and, like Weber’s ‘bureaucracy’, are more-or-less scale

TABLE 1.

WAY OF KNOWING	WAY OF WORKING	EARLY MODERN DISCIPLINES	SOME VARIETIES	SOME POST-ENLIGHTENMENT EXEMPLARS
Reading meanings	Rhetorics from meanings	Natural Philosophy		Science & religion/culture; Philosophy of science
Sorting kinds	Diagnosis/prescription; Crafting from kinds	Natural History	Expt'l histories, Data sets	Sorting using analysis; Crafting with defined materials
Mathematical Analysis by elements	Rationalisation e.g. projectiles	Mixed Maths		Applied Maths
Mathematical Synthesis from elements	Modelling e.g. planetary orbits, or recent Systems biology	Mixed Maths		Simulations
Substantive Analysis	Rationalizing crafts	n/a	Obs or expt'l; Structural or dynamic	Analytical sciences e.g. chemistry, histology
Substantive Synthesis		n/a		Synthetical science & technology, e.g. Synthetic chemistry, Genetic engineering

independent, so the analyses and comparisons can be very macro or very micro, or all grades in between. And where case-studies can be analysed systematically, they can also be connected into schematic histories, again on various scales, from the micro to ‘big pictures’. There is no need or ground for the usual supposition that small histories must be qualitatively different from larger and longer ones.

Such claims may seem rather bold, especially in a climate suspicious of grand narratives, and I recognize that any such method of analysis and synthesis will be plausible only if it connects repeatedly with the distinctions we commonly make as historians, and the stories we tell about variety over space and time. In other words, the components of the approach must be informally familiar as well as schematic; and the schema have to be flexible and elaborate-able. So it may help if I first summarize the WoKs and the WoWs in a Table 1, and then elaborate in the sections that follow, beginning with sorting and crafting, and returning to readings and rhetorics. For each of the WoK-WoW pairs, I indicate the corresponding genres or disciplines, both for the early modern period and for ‘post-1800’. I make this chronological separation because one argument for my choice of elementary types is their close correspondence with the main early modern actors’ categories. What better guide to important analytical categories? — and ones which have salience thereafter, within and alongside the new, post-1800, configurations that also contain elements hardly present before the late eighteenth century.

SORTING KINDS AND CRAFTING

We can begin with a way of knowing that figures in most lists of styles and of disciplines: the activity of describing and classifying, along with allied activities such as collecting, storing and displaying. I have previously called this general activity ‘natural history’ because for several centuries that was the actors’ term for some of its best known exemplars. But we might perhaps simplify matters by not using the disciplinary label as a general analytical term, and instead find another word, less tied to particular times and places. Though there seems to be no such word in normal English, perhaps ‘sorting’ may serve us — if we can extend this verb to include describing and well as classifying. Perhaps ‘sorting’ can be stretched to make a general term for working on and with all sorts or kinds. These sorts are not restricted to objects or to records of objects, but can include observations of processes and happenings, or the results of interventions or experiments, which Bacon called experimental histories. And like all my ways of knowing and working, the sorting type can also encompass mathematical projects, which here may be the sorting of shapes or numerical or other data; thus, for example, sorting records of the height of the tides stands in parallel to collections, or paintings, of birds’ eggs. Similarly, problems of data-handling in present-day STM parallel the problems of maintaining reference collections of viruses. As Bacon would have said, they all relate to memory, broadly understood.

If each of my ways of knowing corresponds to a way of working, what then is the WoW that corresponds to sorting? What is the practical utility of sorting — whether of labelled collections or data sets? One use is the identification of new cases as instances of a particular sort, which enables predictions. This kind of work is well exemplified in much of medicine, and the usual medical terms are easily extended — we can speak of diagnosis and prognosis across all realms of practical action.³ But in domains concerned with creation rather than maintenance, the recognition of suitable materials, data or methods are also basic to activities we might usefully call crafting, such as cooking, dressmaking, house-building or making war. Here recipes of various kinds tell us how to combine and treat materials so as to reach defined ends. Very generally then, prognoses, prescriptions and recipes seem to be the practical correlates of sorting; they require the identification of problems and of remedies, and perhaps of the constituents of problems and remedies, together with rules for use. Of course, there is more to crafts than written instructions — but that is also true of identification, and of all other ways of knowing and working. And if we are interested in the ways in which people operate in their material world, this simple level of sorting, prescribing and concocting is enormously important. These arts are crucial to self-contained societies, but also central to trade, manufacture and professions such as medicine.

READING MEANINGS AND RHETORICS

The previous paragraphs presume cultures which recognize ‘natural kinds’ — as distinguishable, though not separate, from social and cultural categories. How that

distinction has operated in 'non-Western' societies and traditions I must leave to others, hoping the discussions will connect with those of 'naturalization' in the Western tradition, whether in classical Greece, early modern Europe or our present. For whatever the site, we do know that the separation is never complete. As Bruno Latour's book title says, we have never been modern: and even in the more technical ranges of STM, objects and concepts have affective dimensions which help motivate technical work and serve to link it to life's larger questions — of nature and of gods, of virtue and the ends of life.

Understanding the world in terms of meanings is an activity I refer to as 'reading', here drawing on the now general understanding that all aspects of life can be 'read' as if they were texts. Our age lacks a simple term for the study of the meanings of the natural world, but there used to be one. For our early modern predecessors, this was natural philosophy — understood in its general rather than technical aspects, as a branch of philosophy (or theology), rather than a branch of mathematics or physics. Meanings were sought in general principles, such as those of Aristotle, Plato or Paracelsus; and the uses of such readings were in forms of instructive or persuasive speech (or rhetorics) which helped orient lives through discussions of man's relation to nature. If that notion should seem rather abstruse, consider the profession of physic — the highest rank of early modern medicine — the chief business of which was physicians talking. Such physician talk redescribed your illness, and related it to possible causes and to possible ways of regaining the life you wanted. And what served in physic also served if you wanted to know when to set sail or launch a battle, or where to build a house or find a spouse. The advisor's prestige came from experience combined with the capacity to elaborate the dimensions of individual cases in terms of principles. To this activity, a knowledge of kinds and of the principles of crafts, was often important — but it was subsidiary. So too might be a knowledge of the mathematics of the world, as when astrology was served by astronomy.

We meet here the characteristic 'nestings' which become evident when we ask about working knowledges and their relations. In the hierarchies of formal learning in early modern Europe, sorting was preliminary to knowledge of meanings; i.e., natural history was officially subordinate to natural philosophy. But if your main concern was natural history, you might be focused on the parts of plants and their varied arrangements, and for your own purposes you might try to marginalize questions of meaning, or even of use, so as to concentrate on the 'natural kind', as I will discuss in the afterwords. Yet questions of meaning were always there, at a general level if not for the particulars: maybe, for example, the very fact of natural variety was divine, perhaps it was providential. For later generations, the wonder and identification may remain and motivate, though the phenomena be read now as the play of chance. Across history, it seems, most of the issues which proved contentious in STM can be boiled down to difference of 'philosophy', natural and/or social. And if the historiography of STM can re-present technical pursuits as human endeavours, it is because this dimension of meaning never disappears; it remains evidently central to recent fields such as bioethics, climate change, and 'development'.

ANALYSIS AND RATIONALIZATION BEFORE 1750

Aristotelian natural philosophy, which read the world as an organism, undoubtedly aided the work of sorting and showed the purposes in nature, but it was the Pythagorean-Platonic alternative which gave precision and prediction — through mathematical analysis. Complex phenomena were here reduced to mathematical elements: the best example being the Ptolemaic universe where the complicated wanderings of the planets were reduced to circular movements, suitably compounded. Studies of music and statics were developed in similar ways, joining the raft of topics known in early modern Europe as mixed mathematics or intermediate sciences (between mathematics and natural philosophy). This mathematics of nature accompanied the history of nature, and both could be seen as the subsidiaries of the philosophy of nature. Or in simpler terms, less bound to period, mathematical analysis accompanied both the sortings and the readings of the world. And if we ask what were the practical correlates of mathematical analysis, the question largely answers itself: mixed mathematics was about time keeping and navigation, simple machines and optical devices, guns and fortifications. The mathematics of falling bodies was also the mathematics of projectiles, which Newton extended to the heavens.

Such then was the basic structure of early modern knowing: the philosophy, the mathematics and the history of nature; the meanings, the maths and the kinds. And in what we call the Scientific Revolution, the cumulations of sortings and of mathematical analyses fed into or challenged various ‘philosophies’ or frames of meaning. That triadic structure and its dynamic relations seems to me a very useful simplification, and one with wide application; but certainly by the eighteenth century, one needs to add the projects sometimes called experimental philosophy, as often exemplified by Newton’s optics. Experimental philosophy went beyond experimental histories, for it was more than the records of observation. Though mathematical, it dealt with secondary qualities and phenomena such as rainbows which had seemed very distant from geometry. It could introduce new elements, in the form of coloured rays, and suggested how other phenomena might be ‘deconstructed’. In my terms, it showed the way to forms of analysis which were substantive, rather than primarily mathematical.

STM SINCE c. 1800

As Kuhn and Foucault suggested in their very different ways, the successes in STM which are commonly called the second scientific revolution depended on the finding of elements which could serve for the deconstruction of many other areas of natural and experimental histories. Some of these also allowed quantification, some did not. If the distant model for substantive analysis was mathematical resolution, for example of trajectories, the main immediate exemplar was the reformed chemistry of the Lavoisier school. The pattern common across the new chemistry the other emergent sciences involved new kinds of elements such as strata, unit crystals, tissues, cells and elementary machines, and the consequent analysis of objects as ‘compounds’. In some of these ‘compounds’ the elements were juxtaposed or superposed (e.g.

TABLE 2.

RELATIONS OF ELEMENTS	JUXTAPOSED	COMPOUNDED	INTERACTING	SINGLE ELEMENT	BASIC FORMS DIFFERENTIATED
TYPE OF ANALYSIS					
OBSERVATIONAL	Stratigraphy		Functional anatomy; Political economy	Flows of light, heat	Morphology
EXPERIMENTAL INTERVENTION		Chemical analysis	Chemical reactions; Experimental physiology		Analysis of embryos for 'potentialities' of the parts

stratigraphy); some were more intimately compounded (e.g. chemistry), or they were dynamically interacting (e.g. experimental physiology). In many physical sciences, the elements were ‘single’, such as light or heat, and they could be followed through processes, often by quantitative measures. Some of these relations are exemplified in Table 2; they are discussed in the Afterword 3.

The novelty of these new formations was well recognized by Auguste Comte, and the dependence of each on specific ideas by the English Kantian, William Whewell. The need to ‘sort’ these new sciences was evidenced by numerous essays on their classification; and the political imperative for federation by the invention of new institutions, a new meaning for ‘Science’, and much talk of the scientific method.

Much of later STM, through to our time, has centred on the analysis of compounds and flows; the analysis could be qualitative or also quantitative, observational or interventional, exemplary or comparative. The dynamics were well recognized by John Herschel: when a phenomenon could be analysed to the limit, you had elements and a new science; but further work might reveal relations between elements of different sciences, linking them into larger sciences with ‘deeper elements’.⁴ Over the course of a generation, the development of energy doctrines, cell theory and evolution came to exemplify that dynamic.

The same patterns were to be found in new social sciences such as Ricardian political economy or Malthusian analysis of population; and some forms of sociology, notably those of Comte and Durkheim, were directly based on new biological sciences. The new sciences of language ran in parallel, analysing linguistic structures and characteristic shifts over time in ways which were recognized as resembling comparative anatomy. One of the advantages of the WoK/WoW approach is to show the close relations between natural and other sciences, and thus undermine the undue privileging of physical sciences, as seen especially in Anglophone cultures.

Mathematical analysis was less new than substantive analysis, but it was importantly extended, not least in statistics — the reduction of a crowd of numbers to a few key variables — and in other forms of numerical analysis such as Fourier methods. That many physical sciences were now based on substantive elements allowed the characteristic divisions of nineteenth-century physics. Experimentalists, who had

often trained as chemists, explored elements such as heat and voltaic electricity, their possible interactions, and their reactions with the more obviously chemical elements. At the other extreme were explorations of mathematical models and their applications. Emergent in the middle ground were physical theorists who explored possible relations, preferably formal, but available for empirical test.

That's the long view and the big picture. Seen close up, analytical sciences looked like Kuhnian normal sciences, in which the elements and their properties constituted the core of the paradigms. Indeed, one might suggest, the common acceptance of Kuhn's paradigms as a model for science in general is testament to the ubiquity of analytical programmes. The WoK model helps clarify this central activity, as it also highlights the co-existence in and with analytical paradigms of other aspects of STM, notably the readings of meanings and the sorting of kinds — and perhaps also the uses for analysis of synthesizing new objects, to which we shall come after reviewing the practical correlates of analysis.

It is easy to simply assume that synthesis is the practical correlate of analysis, but to leap here to synthesis is to miss the huge importance of analysis in enabling redescription and reclassification, including the refinement of technical processes through better control of inputs and outcomes, partly through quantitation. Generally, the deconstruction of a process may allow the rationalization of its elements. That was the basis of Paris medicine, which viewed diseases as lesions of tissues; it was also the basis of the industrial revolution and its divisions and 'rationalizations' of craft processes. Analysis was the core of a mentality which powered professional, industrial and economic development, from the end of the eighteenth century, partly by the formation and extension of new sciences. These were often created in new kinds of technical schools dominated by teachers keen to be recognised for systematic reconstructions of their teaching fields.

SYNTHESIS IN SCIENCE AND TECHNOLOGY

If analytical chemistry was the main model for the substantive analyses which dominated the early nineteenth century, synthetic chemistry was one model for a range of additional ways of knowing and working which emerged from about 1870, or at least were then so recognized. Another such model was new understandings of mechanical engineering which grew from the formal analysis of machines, from the technical sophistication of inter-changeable parts, and the growing practice of prefabrication. New molecules like new buildings could be assembled from elements, and electro-technical systems came to be seen in the same way, not least in the laboratories of an Edison.⁵

At this point we may re-emphasise that all the preceding working-knowledges continued, sometimes, in isolation, as it were, but also in complex cumulations. Natural history museums were still places of sorting, but much of it was based on new analytical disciplines such as comparative anatomy; and for leading 'biologists' the advancement of these analytical disciplines was more important than mapping life's variety, or considering its philosophical and religious dimensions. The vast

majority of chemical work was analytical, though there were still aspects of sorting, and the increased ability to purify and characterize chemical substances opened new possibilities for crafting — e.g. refined use of opiates in medicine. But if some chemists were already synthesizing molecules before 1850, it was usually to check the analysis. The novelty in the later nineteenth century was the realization that making new kinds of molecules could be a new dimension of science, and of technology. Elements could be put together to change the world, or at least to find new ways of making old things.

The new industries of the twentieth century were based on chemical and electro-technical syntheses, extended into new kinds of pharmaceuticals and computing; with mechanical engineering extended into mass production, and new kinds of physics into atomic technologies. By the end of the twentieth century, new forms of molecular-biological analysis were associated with genetic engineering and synthetic biology, extending the synthetic powers of medicine which had been foreshadowed in Pasteur's work on vaccines and Claude Bernard's on experimental medicine. And in as much as synthesis is a means of making, as well as a demonstration of knowledge, we can say that the scientific and the technological projects were here convergent, and interacting with all the other kinds of working knowledges.

What then of the mathematical dimensions? Again, the answer is familiar by other names — such as mathematical modelling or simulation. For scientific or technological reasons, or both, the results of analysis could be combined, mechanically or digitally, to produce synthetic models. Because mathematical analysis was successful long before substantive analysis, we have mathematical and mechanical models from ancient Greece; a century ago we had analogical computers for tides in harbours; now we have computer models for the motor traffic in cities, for global meteorology, or for metabolism in yeast cells.

But remember that all these sophisticated constructions have depended on numerous forms of sortings and analysis, and on crafts and rationalizations, and all are resonant with meanings. Remember too, that the goals of a project may be 'simpler' than the means, for example when we sort the collected analyses of the genome project, or make simple rhetorics of national power through space projects of huge complexity. Though accumulation is central to my approach, analysis in terms of working knowledges shows that complex cumulations are often marked by contests within or between types, e.g. between analytical techniques and other understandings which are more 'natural historical', whether in bio-medicine or macro-economics. The model serves to highlight these common forms of contestation across many fields, and that the resolutions always depend on contexts. It may be cumulative, but it is not teleological — in that respect, as in its contestations, it may resemble Darwinian evolution.

My hope is that the WoK/WoW approach facilitates historical understandings which cross times, fields and scales, while stressing extra-laboratory practices, including vernacular knowledges and cultural values. It may also help link micro-studies with macro-, and assist 'reintegrations' of history and philosophy of science. That may

sound like a very tall order, but I hope we have begun to show how this approach may fit the bill. The discussion will continue at the end of this volume after you see how colleagues have used the WoK approach for topics on which their expertise is well established.

Brief Introductions to the Papers

Since c. 1800, chemistry has exemplified substantive analysis. Most ‘chemicals’ are seen as compounds, as composed of elements in various (definite) proportions. In the terms here preferred by Hasok Chang, modern chemistry is largely compositional. But that was not true in 1750, where most of chemistry was matter of sorting materials — in mineralogy or the chemical aspects of botany, zoology or medicine, all of which were mostly branches of natural history. How then did chemistry come to be dominated by compositionism, and how was that new understanding related to the earlier forms of description and explanation, including those where the properties of materials were attributed to specific principles, such as acidity or heat? Chang provides a careful and revealing dissection of the issues, including the procedures which chemists knew as analysis, and how changes in those particular operations were related to the wider changes in chemistry.

Bacteriology, as Chris Hamlin shows, was one of the new analytical sciences which were practised alongside chemistry in the later nineteenth century and drew on it heavily for methods and frameworks. As Hamlin stresses, this formation was strangely at odds with the model which many bacteriologists would have liked to pursue. Were they not the experts on a group of living organisms, which ought to be describable and classifiable like other organisms, and perhaps subject to the same kinds of comparative analysis? But such designs proved generally impracticable until the mid-twentieth century. If we want to understand bacteriology before then, we need to drop any notion that sciences, other than natural history, simply correspond to the realms of creation. Bacteriology, for the most part was an analytical science, but the objects of its analyses were not bacteria — they were human and animal diseases, plus various kinds of fermentation. Diseases and fermentations could also be analysed chemically, at least in principle, and some public analysts performed bacteriology as well as chemistry. Hamlin dissects and explains how these various bacteriological and chemical practices were related, and how they connected with natural-historical understandings. He also shows how the issues changed when bacteria eventually became models of life at the molecular level, rather than chiefly representing medical threats and economic tools.

The description and classification of diseases has been a major interest of physicians since the Renaissance, at least, and it has been fundamental to the operation of major hospitals since the early nineteenth century. Nowadays, there are international systems of diseases which cover most of medicine, plus innumerable systems for particular

specialist fields. Most such classifications include forms of medical analysis, such as blood chemistry or histological examination, and they can serve as key frameworks for further analytical research. They also interact with therapeutics in as much as the responses to treatment are fed back into classifications. But in as much as they involve comparison of research across various sites, or the management of cases by many clinicians and agencies, some degree of standardization is required; so too is some articulation with the 'surface' characteristics and symptoms by which patients and their carers order daily life. Ilana Löwy analyses these complex relations through the long history of classifications of cancer. She shows how many kinds of analysis have articulated with the need for agreed 'sorting' systems, and how the elaboration of medicines and the growth of computerization promise new forms of individualization — through the cumulation of manifold analytical judgements.

That molecular biology has depended heavily on 'collections' and in part resembles comparative anatomy (and physiology) is not (yet) central to the image of that vanguard discipline. Its historians, like its proponents, have stressed the role of 'experiment' in separating this new biology from the routines of collection and classification which supposedly marked previous biology as less than a full science — as a matter of stamp collecting rather than physics. But as Bruno Strasser and Sorya de Chadarevian show, the foundational studies on proteins and nucleic acids were projects in molecular anatomy, and the correlation of structure and function often depended on the comparative anatomy of closely related molecules, made available in various kinds of collections. But in drawing attention to this comparative analysis and its relation to previous practices of natural history, they stress that not all such analysis was comparative. In much of molecular biology, as in the rest of biology, analysis was intended to uncover elements common to many, if not all, organisms. It was 'exemplary' rather than concerned with difference. Thus the dialectics of similarity and difference, familiar at the level of natural history, and then at the level of comparative anatomy, were replayed at the level of molecules.

In the last paper, Hans Joerg Rheinberger explores in detail the methods of molecular biology — the experimental techniques which allowed the analysis of molecular structure and interactions. He looks at 'traces' — both material and graphical — and how they were created, sorted and used; how molecular processes were scaled up so they became perceptible, and how the phenomena of these experimental systems were fixed as facts of analysis. He goes on to examine how such facts can be handled, partly through elaborate sorting and dissemination techniques, which make them widely available on data bases; but also through the mathematical synthesis in the new field of 'systems biology', which 'orders' masses of data by building them into model cells, for example. Thus, both at the levels of biological materials and of data, there are interplays between various sortings of fragments and the resultant analysis of the structures and processes from which the traces were isolated. And these analyses are now being made to articulate with syntheses, again both material and digital.

All the papers deal with 'exemplary' historiographical issues, in ways which allow comparison and generalization; they can be read as individual studies or as illumi-

nating connected aspects of recent STM. They show some of the uses of WoKs and WoWs and offer a variety of insights into the relationship between this method and various other historiographic and sociological approaches. At the end of the work I take up some of the issues so raised, and some related issues and possibilities which have been raised elsewhere. But first, the five papers from interested colleagues who were asked to consider the uses of WoKs and WoWs for their favourite fields and approaches.⁶

REFERENCES

1. John V. Pickstone, *Ways of knowing: A new history of science, technology and medicine* (Manchester, 2000, and Chicago, 2001), and "Working knowledges before and after circa 1800: Practices and disciplines in the history of science, technology and medicine", *Isis*, xcvi (2007), 489–516.
2. See discussion in Pickstone, "Working knowledges" (ref. 1), 492.
3. Andrew Abbott, *The system of professions: An essay on the division of expert labour* (Chicago, 1988).
4. John Herschel, *Preliminary discourse on the study of natural philosophy* (London, 1835), 93.
5. Thomas P. Hughes, *Networks of power: Electrification in Western society 1880–1930* (Baltimore, 1983).
6. I am most grateful to the contributors for their papers and patience, and for their useful comments on my offerings. My colleague Jonathan Harwood also commented, and kindly suggested that a relatively simple introduction might help the uninitiated reader. He is usually right.