

INTRODUCTION

EPISTEMOLOGICAL PREMISES

The published papers in which scientists report the results of their investigations are hardly ever literal accounts of the historical processes through which their authors have reached the conclusions they present. Once an investigation, or a publishable phase of a longer research project, has been completed, the actual pathway it followed becomes largely irrelevant to the investigator, who is expected to marshal the best arguments and evidence available to support the claims she wishes to make. Sometimes the case to be presented sufficiently resembles the process of discovery so that the order of presentation may recapitulate the order of investigation; but temporal rearrangements, omissions of false or aborted trails, and other retrospectively unessential steps, are made routinely, with no intention to falsify a record of discovery. Consequently, historians aiming to reconstruct the historical routes to landmark discoveries have long sought other forms of documentation to fill the gaps left open by the published reports of the completed work.

Research records composed of notes and protocols have long played a role in these efforts to understand the origins of what have come to be seen as the established milestones in the development of modern science. Their subordinate role, however, is symbolized by their presence as mere footnotes in many editions of the classical works of science, and the rarity of the publication of research notes relating even to very prominent milestones in the advancement of science.

The use of research records to probe the nature of scientific investigation itself is a recent development in the history of science. With Eduard Dijksterhuis, we could address them as a veritable “epistemological laboratory” (Dijksterhuis in Marshall Clagett, ed., *Critical Problems in the History of Science*, 1962). The purpose of a workshop entitled *Reworking the Bench: Research Notebooks in the History of Science*, held at the Max Planck Institute for the History of Science in Berlin in November, 1998, was to bring together historians who have been exploiting such resources, to share their experiences; to compare the similarities and differences in the materials they had used and the problems for which they had used them; and to measure the potential and scope for future explorations of “science in the making” based on such forms of documentation. The contributions which form this volume are based on papers presented at this workshop or written afterward by participants in the discussions.

Besides their character as traces of a past scientific activity, there is, however, another aspect of research notes, that has yet to receive proper attention. Research notes – or scribblings, as some forms of them might aptly be called – represent a special genre of scientific writing. They are literary activities in their own right, circumscribing a space that lies between the materialities of experimental arrangement, or the unexplored potentials of theoretical formalisms, and the structured formats of printed communication that are released eventually to the scientific community. This intermediate space is shaped, on the one hand, by individual idiosyncrasies, such as are amply illustrated in the case studies of this volume, and, on the other hand, by local, national, or temporal styles – yet to be studied by historians – that have governed the manner in which scientific activity was to be recorded. This space thus belongs to a particular arena for the formation of discourse, but it also escapes those confines, and it has paradoxical features. Research scribblings are, in one respect, very near to, are even quasi parts of, the instruments and objects of research, such as the written display of an arrangement of controls in a biological experiment; at the same time, in their usually elliptic character, they bear an element of subjectivity, unruliness, and privacy from which they must be freed if they are to become elements of a scientific text. In this intermediate space the objects of research have been set to paper, but have not yet become prose. The paper, the protocol, and the notes – whether casually or systematically recorded – are still integral to a materially mediated environment where the subjectivity of the scientist gives free play to its innovative potential. Here much of the individual style of scientific discovery is expressed and consequently can be captured there. By the publication of this volume we hope to promote and encourage the exploration of this uniquely intimate space, to which documents such as those discussed by the participants in the workshop give us salient points of entry.

A HISTORIOGRAPHICAL APERÇU

The historians of science of the wartime and first post-war generations who established the field as a professional scholarly discipline focused on the great canonical achievements of the past. Their attention was fixed, in particular, on the landmark changes in scientific thought from which the foundations of the modern branches of science were believed to have emerged. Only gradually, as they moved beyond the recapitulation of these accomplishments to undertake reconstructions of the practices behind the achievements, to follow their genesis as well as to interpret the meaning of the finished products, did they seek persistently in archival repositories the types of materials that would document such developments. In this process, many new archival sources were unearthed, but sometimes also scholarly work based on unpublished sources that had already been done at the end of the nineteenth century was ignored.

This point can be illustrated particularly in the long history of scholarly study of the critical role in the emergence of modern science played by Galileo. The

substantial collection of theoretical and experimental research notes kept by Galileo and his circle of collaborators and students had attracted considerable interest among historians of science by the turn of the century, but their work was then largely forgotten until Stillman Drake renewed interest in Galileo's manuscripts. Drake (1978) exploited these materials selectively to show that, contrary to the earlier claims of Alexandre Koyré, Galileo had actually performed the experiments he described in his published works. Around the same time, a few of the other great "founders" of the modern sciences, who had left substantial repositories of their work in progress began to draw intense scholarly scrutiny. The rich records of his successive efforts to solve the problems of terrestrial mechanics and planetary motion left by Isaac Newton have provided material for several decades of historical interpretation, and continue to sustain scholarly activity. The retrieval and publication of the notebooks of Charles Darwin on geology, the transmutation of species, and metaphysical enquiries, resulted from a growing interest in the life sciences in the wake of the evolutionary synthesis, and has given rise to an active cluster of scholarly reconstructions of the succession of ideas and evidence from which Darwin's concept of natural selection emerged. Howard Gruber's *Darwin on Man* (1973; 1981), is an early, and still rare example of the combination of such reconstruction with a theoretical study of the nature of scientific creativity.

For a long time laboratory notebooks attracted even less attention than other types of research records, such as correspondence, for example. Philosophers of science in the first part of the twentieth century had given priority of place to the construction of theory, and did not show great interest in the particulars of experimentation. Symbolic of the relative neglect of sources that document experimental activity itself are the laboratory notebooks of Antoine Lavoisier. Twelve bound volumes, recording most of the experiments Lavoisier carried out from the start of his investigation of the "processes that fix and release airs" in 1773, to his studies in fermentation and the composition of organic substances in 1789, have been readily accessible since the end of the nineteenth century. In *La révolution chimique*, published in 1895, Marcellin Berthelot provided an abstract of the contents of these volumes, including a chronology of the topics of the experiments, and selected comments made by Lavoisier in the notebooks, but without giving the substantive descriptions of his procedures or results. Subsequent historians have cited portions of Berthelot's abstracts to summarize phases in Lavoisier's experimental activity, but until recently no one gave more than passing attention to the original notebooks. Berthelot's abstract satisfied them, so long as historians remained more interested in the development of Lavoisier's ideas than in his experimental practice. The challenges to analytical philosophy of science brought about by the writings of Thomas Kuhn and others, and the increasing interest in the nature of scientific practice itself have, during the last three decades, changed these priorities sufficiently to greatly enhance the value currently attributed to documents such as Lavoisier's laboratory notebooks.

A pioneer in the serious investigation of the contents of laboratory notebooks

and the illumination they can provide concerning the process of discovery has been the late Mirko Grmek. Given the task of ordering and cataloguing the huge collection of manuscripts left by Claude Bernard, Grmek saw that the many volumes of laboratory notebooks included among those documents provided a means to reexamine the well-known retrospective narratives of his experimental discoveries that Bernard himself had given in *An Introduction to the Study of Experimental Medicine* (1865) and in other published writings. Grmek showed that for several of his major discoveries, Bernard's later narratives were incompatible in significant ways with the experimental record.

Since the 1980's there has been a small but growing stream of historical work based on, or at least involving laboratory records kept in a broad range of centuries and disciplines. The editors of the present volume have wanted to draw attention to this work, which remains overshadowed by other more highly visible fashions in the field; to raise a number of overarching issues arising from the nature of this work, and to encourage the further application of the methods illustrated in the individual contributions to frame historical narratives, and to provide deeper epistemological perspectives on the research process.

A NEW BRANCH OF THE HISTORY OF SCIENCE?

The contributions to this volume bear witness to the spread of interest in "science in the making" that is leading historians, philosophers, and sociologists increasingly to base their accounts on information that research notebooks can provide. Notebooks represent a peculiar source that can demand more ingenuity, more technical effort and experience, and more background knowledge for the reconstruction of the activity they document than does the typical interpretation of published sources. Those who have undertaken the study of such notebooks have, therefore, had to become specialized in such techniques as deciphering difficult handwriting, reading between the lines of statements expressed in compressed, elliptical form, and inferring the intentions behind pages that record only operations. In some cases a feeling for paper qualities, ink colors, and watermarks, or the ability to transform intuitively small hints from the size of a piece of paper or the smell of a box has been essential to transform scattered records into a chronological order. The individual papers represented here illustrate how diverse the problems posed by particular records can be. Are there, nevertheless, common perspectives that emerge from these singular pursuits? Those who participated in the workshop on which this volume is based recognized that beneath the many superficial dissimilarities in their specific endeavors lay a deeper commonality of commitment, and a shared craft. The variety of approaches adapted to particular circumstances were connected in many ways to a broad and increasing array of techniques and methods available to historians who want to study notebooks. They raise the possibility that some of the tacit knowledge of individual scholars can be transformed into the precepts of a methodological canon.

With a few exceptions, those scholars whose work is included in this volume have had to journey to the archives in which research records are preserved, or to have obtained them from the scientists who kept them, and to work with the original documents themselves, or with xerox copies prepared for them personally. The publication of such records has remained a problem. Only when records take the form of more or less coherent texts, as in the case of Darwin's notebooks, have they been accessible to traditional editorial methods. In other cases, as in the publication of Galileo's archival materials, the records of experimental activity have been left out because of their fragmentary, non-discursive nature. The opportunity to make high-quality reproductions of research records electronically available on the internet together with work on them, has now radically changed this situation. It entails the option to make such materials much more widely available to the community of historians of science thus creating new challenges for scholarly work on these sources.

Rapidly advancing technologies are also providing an arsenal of analytical tools to disentangle some of the deeper mysteries of research notebooks. Traditional sidelight photography to reveal traced lines in manuscripts can now be supplemented by the analysis of inks through the methods of nuclear physics. The results of such examinations, together with information about paper sizes, watermarks, and handwriting styles can be incorporated into databases freely accessible to the community of scholars. The study of research notebooks is thus taking part in a rapidly evolving methodology of manuscript research, which has become a field comparable to archaeology or palaeontology, combining the traditional investigative hermeneutics of the humanities with the analytical acumen of the natural sciences. The solution of notebook puzzles that have hitherto occupied single scholars alone can now become collective enterprises. As far as we can foresee, however, many of those historians who choose to reconstruct science in the making will still experience the toil and the pleasure of tracking down original documents that may have landed somewhere in an archive, or that may still be in the possession of a living scientist or her heirs.

The problems encountered in reconstructing research processes documented by notebooks are, of course, not limited to technical considerations concerning their physical condition. Most research notes are taken for the benefit of a very restricted audience, sometimes only for the individual researcher himself. Because the recorded information serves in this way only as a supplement to memory or to the constant informal communication that takes place among the members of a research group, it may be stated in highly abbreviated, and to outsiders cryptic form. For a successful analysis, the modern interpreter must bridge the gulf between the notes that survive and their original context which has disappeared, reconstructing the knowledge, the skills, the objects, and the instruments that were taken for granted by the author of the notebook. To gain access to this implicit background knowledge, it is necessary to go beyond the notebook itself, to exploit other sources such as published papers, contemporary textbooks, institutional records, biographical information, and material artefacts.