Epilogue

There are diverse ways of going amiss. Not all of them can best be characterized in terms of error—experimental error is too limited a technical concept for this purpose. The episode of Krebs's discovery of the urea cycle is a case in point (chapter, "Concepts from the Bench: Krebs and the Urea Cycle"). In the course of his research, Krebs reached a dead end. All his experiments had worked fine, but he was unable to answer his research question with the material and conceptual tools that were available to him. Obviously, something was going amiss, but he was not in error. In a similar vein, the investigation of glycogenesis and the development of in vitro techniques for analyzing subcellular particles (chapter, "Experimental Reorientations") indicate that the concept of error is too closely associated with "proven wrong" to offer a suitable characterization for the openness and indeterminacy of the actual situation in experimental research.

Going amiss comprises two distinct but related themes. The first theme concerns the occurrence of disturbances and the encounter of impediments in everyday research. Of course, as several papers in this volume point out, going amiss is a common feature of scientific experimentation. Scientists frequently go amiss while attempting to get it right. Sometimes they are successful in this endeavor—they get it right; and sometimes they are not—the project fails. But precisely because going amiss is an integral part of scientists' everyday research, we need to consider its function in experimental practice. Therefore, a comprehensive analysis of the process of knowledge generation in experiment must take account of the common phenomena of going amiss. Directing our attention to scientists' encounter with errors, dead ends, disturbances and the like sheds new light on the process of knowledge generation.

The second theme is the experimental result, its epistemic status, and its career. The concept of error is pertinent to the evaluation of the status of knowledge claims generated in experiments. Such an inquiry need not necessarily reflect the actor's perspective. Building on both the actor's appraisal and the analyst's assessment of the experimental situation, it seeks to draw out general features of the occurrence of error. A typology of error may demonstrate how those claims that proved wrong can be analyzed in terms of sources of error (chapter, "Error: The Long Neglect, the One-Sided View, and a Typology"). It aims at systematic analysis of possible sources of errors in research procedures and thus may go beyond the actor's methodological concerns.

The episode of the globule hypothesis (chapter, "Error as Historiographical Challenge: The Infamous Globule Hypothesis") brings to the fore the distinction between the two themes. It is insightful to reconstruct the microscopists' negotiations among themselves as a debate about whether that hypothesis was erroneous, and we may in hindsight conclude that certain versions of that hypothesis were indeed erroneous. We may analyze the nature of this error in terms of its possible sources. However, it is awkward to render the investigation of the microscopists' research practice in terms of error. Confusion reigned and the practitioners began discussing whether the methods they used were correct, effective, or faulty. Unlike error, the notion of going amiss is conducive to this kind of analysis.

Analytical Perspectives

To study the phenomena of going amiss, it is crucial to distinguish carefully between different historiographical perspectives in which these phenomena can be approached. At least five domains of analysis need to be recognized. First, there is the domain of scientific practice. How do scientists deal with the possibility that something is amiss in their experiments? The study of the missing rain (chapter, "Distinguishing Real Results from Instrumental Artifacts: The Case of the Missing Rain") traces in detail how late eighteenth- and nineteenth-century investigators tried to solve the height-catch problem. It describes how the researchers sought to establish whether they were led astray by an instrumental artifact, or by the intervening physical conditions; or, alternatively, whether the observed difference in rainfall was a real difference. The issue of learning (chapter, "Learning Without Error") gives another twist to this perspective, exemplifying how scientists address the problem of error as a research topic in the study of processes of learning.

Secondly, there is the domain of scientists' discourses about their actual research practice. Do they discuss the problem of going amiss when they communicate their research? If so, how much attention is given to this discussion? What terms do they use to report it? And how do they evaluate their situation vis-à-vis the possibility of going amiss? The case of the globules shows that in the early nineteenth century microscopists commented extensively in their publications on this problem (chapter, "Error as Historiographical Challenge: The Infamous Globule Hypothesis"). The practice of reflecting on obstacles in experimental research has changed considerably since the early nineteenth century. Thus, analyzing how the textual forms of reporting errors and other impediments change over time would be a fruitful project for future research.

Thirdly and closely related, there is the domain of scientists' appraisal of scientific results. How do they evaluate experimental outcomes? When and why do they decide that a particular claim to knowledge is erroneous? Does this evaluation change over time, and if so, how and why? Fizeau's ether drift experiment elicited a variety of responses to its result by the physics community, ranging from approval and silence to opposition (chapter, "Going Right and Making It Wrong: The Reception of Fizeau's Ether-Drift Experiment of 1859"). The account of these responses traces how they changed from complete agreement to general rejection.

Fourthly, there is the domain of retrospective conceptual analysis. How can we characterize the nature of erroneous results? What does it mean for a result to be erroneous? As mentioned above, one approach is to identify possible sources of error in an experimental arrangement. The classification of sources of error yields a typology that is designed to capture the epistemic structure of the experimental argument. This approach is called "probing experiment with error"; in this scheme error serves as a tool of inquiry to throw light on the elements that comprise the process of generating experimental knowledge (chapter, "Error: The Long Neglect, the One-Sided View, and a Typology").

The nomenclature that we offer in the introduction to this volume serves both the scholars who seek to uncover the actors' usage of terms related to going amiss and the scholars who devise their own terms to shed light on the nature and role of impediments in experimentation. The contributions illustrate various elements of the proposed nomenclature and give numerous indications of how it could be refined, modified, and expanded. For example, in some situations, organic chemists actually referred to their experimental outcome in terms of "surprise" (chapter, "In the Thick of Organic Matter"). In contrast, the distinction between "waste" and "filth" (chapter, "The Scent of Filth: Experiments, Waste, and the Set-Up 12) is clearly not an actors' distinction. It is introduced to characterize an important difference between two kinds of unwanted or unintended effects. The first kind stands for those side effects that are not only a necessary by-product of experimental practice, but also help assure the experimenter that his or her apparatus is in working order. The second kind represents those effects that cannot be interpreted within the accepted theoretical framework. Effects of the second kind may or may not bring about novel empirical insights.

In contrast to the nomenclature offered in the Introduction, a typology of errors does not aim to capture the intricacies of scientific practice. Rather, it provides, as we have indicated, tools for the analysis of erroneous results in terms of their different sources. The classification of computational errors that von Neumann outlined in his studies of large scale computing machines is a case in point (chapter, "Going Amiss in Experimental Research"). His typology reflects the functional principles of these machines. Moreover, the comparison of these errors with pathological functions is an instructive device for understanding the difference between artificial and living systems.

Finally, bringing together the various investigations from the different domains provides the basis for the overall epistemological evaluation of the role of going amiss in science. The productivity of going amiss now becomes apparent.

The Productivity of Going Amiss

The study of going amiss is productive in a double sense. First, the exploration of what was going amiss in experimentation is often an extremely important step in "making it right". Erroneous results may even stimulate the advancement of an

entire scientific field. To be sure, not all cases of going amiss are productive. When Dewar interpreted the anomalous results in the specific weight of gases as indicating a new form of Nitrogen, he maneuvered himself into a dead end and never managed to get out of it (chapter, "A Pioneer who Never Got it Right: James Dewar and the Elusive Phenomena of Cold"). However, most of the episodes related in this book demonstrate the productivity of going amiss. They further underline that there are different ways in which going amiss can be beneficial.

Going amiss can be productive by eliminating options. In the case of the investigation of liquefying Hydrogen, Dewar reached another dead end. However, this time his research created a background that was productive for the work of his contemporaries who had become acutely aware that this line of research did not lead anywhere. Going amiss can also be fruitful as a motivation to re-direct research. Thenard encountered an anomaly in his experiments—something happened that should not have happened given the standard concepts of his time (chapter, "In the Thick of Organic Matter"). The encounter took him by surprise and re-directed his attention from the technical concerns of his experimental agenda to novel conceptual questions. This re-direction of attention initiated a new line of research that resulted in the formation of an entirely new discipline.

Both Krebs and Faraday exhausted their conceptual tools in the course of their respective research pursuits (chapters, "Concepts from the Bench: Krebs and the Urea Cycle" and "How Experiments Make Concepts Fail: Faraday and Magnetic Curves"). This led them to retreat and re-assess the experimental situation. In both cases, only the reconceptualization of the experimental situation made it possible for them to advance. In the case of the β decay, a controversy arose among different groups of investigators about whether the spectrum of the decay was continuous or discrete (chapter, "The Spectrum of β Decay: Continuous or Discrete? A Variety of Errors in Experimental Investigation"). The various groups could not reach an agreement. The ongoing controversy motivated Ellis and Wooster to rethink the experimental approach and thereby free it from all disputed hypotheses. Here it was not a reconceptualization of the experimental situation but its replacement with an altogether different experimental approach that made it possible to resolve the controversy and establish a new physical fact. All these episodes illustrate that for the scientific researcher and indeed for the whole community the comprehension of going amiss can be productive in many ways.

Secondly, the inquiry into going amiss is a profitable resource for historians and philosophers of science. In the case of Fizeau's ether drift experiment, the contemporaneous actors' positive response is as uninformative as the present-day negative assessment (chapter, "Going right and making it wrong: The reception of Fizeau's ether-drift experiment of 1859"). However, in hindsight, one can trace the gradual transformation from an unproblematic experiment to an experimental result that today is no longer of interest to the practitioners. This case is instructive because it can give clues as to how an experiment may or may not enter the canon of a discipline. Examining the dynamics that underpins this process of exclusion gives historians and philosophers of science insight into the way in which scientific claims coalesce into knowledge. By contrast, the episode of the globules is instructive because

the investigation of the scientists' discourses about the possibility of going amiss reveals previously neglected driving forces for scientific advancement, in particular, the productivity of the proliferation of conflicting experimental results (chapter, "Error as Historiographical Challenge: The Infamous Globule Hypothesis").

This volume places the phenomena of going amiss in the limelight. Understandably, scientists do not wish to be remembered for their errors, confusions and dead ends; they want to succeed, not to be detained by going amiss. Still, they cannot avoid in their daily routine the possibility of going amiss which comes in a variety of unforeseen ways. The volume captures the many ways in which experimenters may go amiss. At the same time, it argues that historians and philosophers of science may find the phenomena of going amiss rich and productive. This should not come as a surprise since going amiss is part and parcel of the practice of experimental research. What is surprising, however, is the fact that so far there has not been an attempt to address this unwieldy theme in a systematic way. Our volume aims to fill this lacuna and at the same time to turn the methodological analysis of impediments and hurdles into a rich tool for better understanding the process of generating knowledge in experimental research.

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