3 REPORTING THE EXPERIMENT

THE CHANGING ACCOUNT OF SCIENTIFIC DOINGS IN THE *PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY,* 1665–1800

Experimental reports tell a special kind of story, of an event created so that it might be told. The story creates pictures of the immediate laboratory world in which the experiment takes place, of the happenings of the experiment, and of the larger, structured world of which the experimental events are exemplary. The story must wend its way through the existing knowledge and critical attitude of its readers in order to say something new and persuasive, yet can excite imaginations to see new possibilities in the smaller world of the laboratory and the larger world of nature. And these stories are avidly sought by every research scientist who must constantly keep up with the literature.

If each individual writer does not think originally and creatively about how to master recalcitrant language in order to create such powerful stories, it is only because the genre already embodies the linguistic achievement of the three hundred years since the invention of the scientific journal necessitated the invention of the scientific article.[1] The experimental report, as any other literary genre, was invented in response to a literary situation and evolved through the needs, conceptions, and creativity of the many authors who took it up. The corpus of the genre is not only immense, it is rich and varied, synchronically and diachron-

1. For a comprehensive view of the rise of scientific journals see David A. Kronick, *A History of Scientific and Technical Periodicals.* A. J. Meadows, *Development of Science Publishing in Europe* suggests some of the historical variety of scientific publication. A. J. Meadows, *Communication in Science,* and William Garvey, *Communication: The Essence of Science,* describe some features of the current system of journal communication.

ically. Despite familiar pedagogical prescriptions, the experimental report is no single narrow form.

Fiction, Nonfiction, and Accountabilities

The extent of literary construction is not diminished for the genre's being nonfiction. Nonfiction—a concept defined only negatively, for its not being the regular meat of literary investigation—presents serious literary questions of the representations of worlds in words. Given modern critical understanding and modern epistemology, the traditional distinction between that which is made up (and therefore of literary interest) and that which reflects the world (and therefore trivial linquistically), obscures rather than illuminates. Few today would contend that signs are unmistakable and predetermined reflections of things.

Some contemporary theorists would in fact reduce all texts to fiction, claiming reference itself a fiction.[2] While much may be said for this position, nonfiction creation incorporates procedures tying texts to various realities. An introspective phenomenology of religious experience or a political speech or an annual report is no less nonfiction than an account of doings in a room at a physics laboratory. Differences of nonfictions hang on differences of accountabilities (of both degree and kind) that connect texts to the various worlds they represent and act on.

The concept of accountabilities will run throughout this book, as we look at how the various writers and readers, situated in certain communities, following the habits and procedures of observation and representation, are restricted in what they say, do and think by empirical experience. Many mechanisms (of training, argument, criticism, normative behavior, application, sanction, and reward) realize and elaborate this fundamental commitment of the discourse. The chapters that follow will examine numerous accounts of empirical experience that play crucial roles in scientific communication, the emergence of standards and procedures for those accounts, means for reconciling accounts and developing more generalized accounts consistent with more specific accounts, situations where discrepancies or uncertainties within or between accounts call for further accounts. The scientific enterprise is built on accounts of nature, and the development of scientific discourse can be seen as the development of ways of presenting accounts.

2. Core documents for this position are Jacques Derrida, *Of Grammatology*, and Michel Foucault, *The Order of Things*.

Other types of communities may have other fundamental accountabilities and means of enforcing and elaborating these accountabilities. Sacred texts, for example, provide the constant ground, pattern, and reference point for communication in some religious communities; all discourse is held accountable to the sacred text by means of discourse style, conceptual assumptions, overt quotation and paraphrase, psychological rewards of certainty, social rewards for piety, and ostracism for blasphemy. Legal discourse is held accountable on one hand to a hierarchically arranged series of court decisions, laws, and constitutions, and on the other to evidence gathered through procedures defined by the system and represented in a manner established by tradition and explicit rule. In certain types of literary critical discourse, as exemplified by one text examined in the last chapter, the fundamental reference point is a subjective experience of the text; Hartman's article mobilizes many mechanisms to identify that experience and transfer it to the reader. The whole enterprise rests on that experience and is elaborated through the socially recognized means of developing such accounts.

As developed here, the concept of accountabilities is closely related to Ludwik Fleck's definition of a fact as a "stylized signal of resistance in thinking" within a thought collective (98). That is, following the thought style (including styles of perception, cognition, and representation) of a group of people engaged in intellectual interchange, certain statements limit what can be appropriately said and thought within the collective. Certain of the constraints are what Fleck calls active elements, actively produced by the thought style; others are passive, where the discourse system so to speak bumps into objects outside itself, which by the thought style must be respected by the thought collective. Facts are perceived and represented through the actively constructed thought style, but reflect the passive constraint imposed by external conditions. (A more complete discussion of Fleck's analysis of facts is presented in chapter 11.)

These facts accepted by the community form the basis for the accountability, as I use the term. These facts, outside the immediate active elements of discourse, must be brought into the discourse and accounted for. The process of holding the text accountable to these facts serves to shape the discourse. The mechanisms of accountability permeate the creation, reception, and textual form of statements in the collectives holding themselves accountable in this way.

Fleck goes on to characterize the thought style of contemporary science as actively seeking to include a maximum of passive elements despite their tendency to disrupt other accepted active elements. Put more simply, the fundamental commitment is to empirical experience. Scientific discourse, therefore, is built on accountability to empirical fact (as of course characterized within the thought style of science) over all other possible accountabilities (such as to ancient texts, theory, social networks, grant-giving agencies), and must subordinate other forms of accountability (that is, those other forms of accountability which do form part of the scientific thought style) to the empirical accountability.

The Experimental Report as a Historical Creation

Although many kinds of communication pass within scientific communities, experimental reports are close to the heart of the accountability process, for experimental reports present primary accounts of empirical experience. Experimental reports attach themselves to the nature that surrounds the text through the representation of the doings, or experiment. How does the world of events get reduced to the virtual world of words? How did the conventions and procedures for this reduction develop? What are the motives and assumptions implicit in the rhetoric and procedure? And what are the accountabilities that limit statements, ensuring the influence of the evidence of the world on human conception? These are equally questions of literary theory and rhetoric as of philosophy of science, for what appears to philosophy of science as the problem of empiricism, appears to rhetoric as the problem of persuasive evidence, and to literary theory as the problem of representation.

One place to turn for answers to these questions is the early history of the experimental report, for the formation of a genre reveals the forces to which textual features respond. A genre consists of something beyond simple similarity of formal characteristics among a number of texts. A genre is a socially recognized, repeated strategy for achieving similar goals in situations socially perceived as being similar (Miller). A genre provides a writer with a way of formulating responses in certain circumstances and a reader a way of recognizing the kind of message being transmitted. A genre is a social construct that regularizes communication, interaction, and relations. Thus the formal features that are shared by the corpus of texts in a genre and by which we usually recognize a text's inclusion in a genre, are the linguistic/symbolic solution to a problem in social interaction.

That a well-established, successful genre is usually realized in relatively static formal features should not hide the social meaning and dynamics of a genre, no more than the active reality of a performed Beethoven quartet should be obscured by the sheet music. By examining the emergence of a genre we can identify the kinds of problems the genre was attempting to solve and how it went about solving them. The history of the experimental report shows how a certain kind of detailed picture of a laboratory event became the standard and how particular information became essential to a successful telling. We can also see forming, as the genre takes shape, a particular literary community with certain critical expectations.

The *Philosophic Transactions of the Royal Society of London,* the first scientific journal in English, carries the main line of the development of scientific journal writing in English through the nineteenth century. Here I follow the development of the genre of experimental report in the pages of the *Transactions* from its founding in 1665 until 1800, when a number of familiar features of the experimental report were firmly in place.

This chapter focuses entirely on the internal development of the genre. Although the genre of experimental article has origins in essay, epistolary, and journalistic writing of the seventeenth century (Frank; Houghton; Kronick; Paradis; Sutherland), the internal dynamics of scientific communication within a journal forum reshape the initial sources to create a new communicative form, powerful enough to influence other forms of communication and the social structure of the community which uses it. Chapter 4 will begin to explore the relations between the existing book publication of scientific arguments and the newly emerging journal article. Chapter 5 will consider the kind of social structure out of which journal publication arose and the power of journal communication to transform the social structure of science.

Method

This study is based on an examination of all articles (about 1000 altogether over 7000 pages) in volumes 1, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80, and 90 of the *Transactions.* From these volumes all articles using the word experiment either in the title or running text were then selected for closer examination. Then those articles providing only secondary accounts of experiments were eliminated, leaving only articles written by the experimenter reporting on new experiments. This procedure left a remainder of about 100 articles to be analyzed.

Because of the changing character of the writing in the articles and because of the individual character of each separate article no quantitative comparisons appeared useful, so I resorted to the traditional method of literary criticism, descriptive analysis of each of the separate articles. This method did allow me to explore the varying features of writing as they presented themselves. However, such individual description makes generalization difficult. In order to facilitate the comparison and continuity among the many cases, I narrowed my descriptive analysis to a set of specific questions.

1. To what kind of event does the term "experiment" refer?
2. How fully and in what manner are experimental events described?
3. How fully are apparatus and methodology described? How fully and in what way are methodological concerns discussed?
4. How precisely and completely are results presented? What criteria of selectivity are used? How much and what kind of discussion and interpretation are present?
5. Is the experiment presented as a single event or as part of a series of experiments? In a series, what is the principle of continuity?
6. How is the account of the experiment organized? How are series of experiments organized? Where does the account of experiment or experiments fit within the organization of the entire article?
7. What is the rhetorical function of the experiment within the article?

To facilitate the organization of the material of these separate analyses, particularly with the intention of clarifying historical trends, I then synthesized the analyses from each volume examined, thus forming generalizations about the character of the experimental reporting in each time period. From this collection of chronologically arranged syntheses I extracted the major themes and trends as presented below. The story I will be presenting thus has been filtered several times through my own personal interpretive, selective, and synthetic judgments. I will present detailed evidence from the texts to illustrate and support the story I present, but I will not be presenting all the trees in the forest. If I were to tell more I would risk the reader losing sight of the shape of the forest I believe I have found. On the other hand, I have no more impersonal way of either reconnoitering the shape of the forest or communicating and demonstrating that shape. This is always the dilemma of attempting to make sense of historical and literary material which incorporates the complex actions of many individuals. In terms of persuasion, this essay must rest in the short term only on the impression it gives of a plausible story and in the long term only on whether others crossing the same terrain find the shapes presented here recognizable and useful.

Another consequence of working from individual accounts of the products of many individuals, each reacting to specifics of individual situations, is that the overall trends are likely to wash out many individual variations as well as to appear more uniform than they in fact are. When looking at all the trees in the forest, I find a somewhat more ragged shape than will emerge here, although I will attempt to indicate where the raggednesses are.

The Changing Experiment

Despite our current belief in experiment as one of the foundations of science, only a small part of the volumes examined up to 1800 were devoted to reporting on experiments. Both in terms of the percentage of total articles and percentage of pages, experimental articles accounted for only 5 to 20 percent of each volume through volume 80. Only in volume 90, opening the nineteenth century, did the percentages rise substantially to 39 percent of the articles and 38 percent of the pages.

Until 1800, however, it is clear that experiments were only one of many types of information to be transmitted among those interested in science. The most articles and pages were devoted to observations and reports of natural events, ranging from remarkable fetuses and earthquakes, through astronomical sightings, anatomical dissections, and microscopical observations. Human accomplishments received attention with accounts of technological and medical advances, travelogues of journeys to China and Japan, and an interview with the prodigy Mozart. The reportable business of natural philosophers was hardly restricted to experimenting or even theorizing, which received even less space than experiments.

The relative paucity of experimental accounts should remind us how much the importance we attach to experiments is a function of the rise of the experimental article as a favored way of formulating and discussing science. Although experiments may have their ancient precursors and early books may have experimental accounts embedded within them, the creation of the experimental article has helped create our modern concept of experiment.

Those reported events identified as experiments change in character over the period 1665–1800. The definition of experiment moves from any made or done thing, to an intentional investigation, to a test of a theory, to finally a proof of, or evidence for, a claim. The early definitions seem to include any disturbance or manipulation of nature, not necessarily focused on demonstration of any stated preexisting belief, nor even with the intention of discovery. With time, experiments are represented as more clearly investigative, corroborative, and argumentative.

In the first volume of the *Transactions*, a number of experiments reported are simply cookbook recipes for creating marvellous effects or effects of practical use, such as the directions for coloring marble internally "of use to artisans" (1:125).[3] Elsewhere experiments are a method of investigating nature, treated on a par with observations, as in the formula often appearing in the pages of the journals: "experiments and observations." Observations were made upon undisturbed or unmanipulated nature while experiments involved human intervention. That intervention need not imply intention of investigation; for example, one series of experiments grew out of a cook's pickling of mackerels. Only after several days, when the cook noticed that the broth had turned luminescent, did the master of the house identify the phenomenon as something worth observing (1:226–28).

By volumes 5 and 10 the definition of experiment had narrowed in most cases to a conscious investigation of phenomena involving some doings or manipulations, even though cookbook novelties appeared as late as volume 20 (20:42–44, 87–90, 363–65). These experiments, however, are presented as simply allowing the conditions for brute nature to reveal itself. The meaning of the experiment is simply what is observed upon its occurrence. For example, in volume 10 Christian Huygens and Denis Papin report on a series of experiments to "know, whether the Vacuum would be of use to the Preservation of Bodies" so they placed various flowers, fruits, and other comestibles in vacuums for various periods of time and observed (10:492–95). Retrospectively, such experiments seem part of a broader investigation of the atmosphere, but nowhere do the reports of these or similar vacuum experiments suggest that questions, theories, problems, or hypotheses were being explicitly explored or tested.

Only in cases of overt controversy are assumptions or hypotheses explicitly set out to be tested, for then the experiment becomes a means of adjudicating between two or more proposed views. Again in volume 10, as part of a report of another series of vacuum experiments, Huygens and Papin, prompted by comments by another investigator,

3. This and similar articles are part of a regular program of reporting on the trades, according to Kathleen H. Ochs, "The Failed Revolution in Applied Science," and Marie Boas Hall, "Oldenburg, the *Philosophical Transactions*, and Technology."

present their alternative view of the reasons for collapse of lungs and then describe a specific experiment that led them to their conclusion.

By volume 20 several experiments have clear hypothesis-testing or debate-solving functions. Experiments are being recognized as created events designed with specific claims about nature in mind. In volume 25, for example, Francis Hauksbee[4] comments, with some pleasure, at the use of experiment as a way to test hypotheses: ". . . the greatest Satisfaction and Demonstration that can be given for the Credit of any Hypothesis, is, That the Experiments made to prove the same, agree with it in all Respects, without force" (25:2415–17).

In volume 30 five articles place their experiments in the context of extensive discussions of debates which the experiments are set to resolve, such as whether a vacuum is truly empty. In this particular case, the experimenter Jean T. Desaguliers spends a full page reporting on a previous vacuum experiment he had made and the particular objections a group of plenists had to his procedure, against which he sets his current work (30:717–18). In most cases the experiments provide rather direct observations concerning the issue at hand, as in the preceding example where pairs of different objects were dropped in an evacuated column to see whether the time of fall were the same for each. But at least in one case the experiments were at some remove from the issue of contention, indicating that experiments were now accepted within the context of a complex of accepted knowledge rather than simply as brute demonstrations. Desaguliers, in order to dispute Leibniz's explanation of barometric measurements during rain, enters into a theoretical discussion of the weights of bodies falling through a medium, which discussion he then supports through a series of ingenious experiments employing neither barometers nor atmosphere. The experiment stands on established background knowledge for its construction and interpretation (30:570–79).

At this point the experiment's role of adjudicating disputes as to the brute truth of nature starts to shift toward establishing the truth of general propositions that are not necessarily disputed by anyone. Experiments stop being a clear window to a self-revealing nature, but become a way of tying down uncertain claims about an opaque and uncertain

4. Francis Hauksbee and John Desaguliers, as frequent contributors to the *Transactions* throughout the early part of the eighteenth century, seem to have had significant influence on the development of the experimental article. Studies of their development as writers of experimental science would help fill out the story of the evolution of the experimental report. Similarly, a study of the innovations and influence of William Herschel as a scientific writer ought to reveal significant trends in the latter half of the eighteenth century.

nature. The meaning of an experiment is no longer the simple observation of what happens. An experiment is to be understood only in terms of the ideas that motivate it, for nature is no longer considered to be so easy to find. Through volumes 50 and 60 the experiments become increasingly couched in terms of problems—things that despite our familiarity with phenomena we do not understand. In volume 60, Joseph Priestley describes his puzzlement concerning the nature of the electrical phenomenon he calls "lateral explosion" which did not behave the expected way in a series of simple exploratory experiments: "I do not remember that I was ever more puzzled with any appearance in nature than I was with this; and, in the night following these experiments, endless were the schemes that occurred to me, of accounting for them, and the methods with which I proposed to diversify them the next morning, in order to find out the cause of this strange phaenomenon" (60:195). A series of experiments follow, logically solving the puzzle, part by part. Experiments are now clearly represented as part of a process of coming to conclusions. Priestley in another article on electricity comments on the personal intellectual consequences of an experiment: "With respect to the main object of my inquiry, I presently satisfied myself, that the conducting power of charcoal . . ." (60:214).

By volume 80, experiments are subordinated to the conclusions the authors have come to; that is, the experiments are ways of proving or supporting general claims. Hypotheses are presented up front and the series of experiments follow. Priestley, for example, now adopts language of proof rather than of discovery: "That my former supposition . . . is true, will appear, I presume, from the experiments which I shall presently recite" (80:107).

By volume 90 authors talk about the necessity of establishing general knowledge and the role of experiment in testing our beliefs as well as filling out knowledge. William Henry comments at the beginning of his report of experiments analyzing muriatic acid, "The theory of the formation of acids . . . must be regarded as incomplete, and liable to subversion, till the individual acids now alluded to have been resolved into their constituent principles" (90:188). Experiments test and justify the general claim, which is part of a larger system of general claims. The language of general proof holds sway: "The above facts prove, that the combination of oxygen and muriatic acid . . ." (90:194).

Methodological Concern

As experiments gain an argumentative function, the reports explain more fully how the experiment was done and why the particular methods were chosen. How nature is prodded is recognized as affecting nature's response. Debates over differing results focus attention on differences in experimental methods and conditions. Methodological care enables experiments to be used as investigative tools and then as proofs. Investigators, in order to satisfy their own problems, make subtle methodological distinctions among different experiments within the same series. Then toward the end of the period, when experimenters start arguing general propositions, the meaning and validity of the experiment depends on proper methodology.

In the early volumes how an experiment was performed was generally mentioned in passing, simply to let the reader know what kind of experiment was done. In volume 1, issue 3, for example, the editor, Henry Oldenburg, describes a series of observations and experiments made by Thomas Henshaw on the putrefaction of May-Dew. In each of the series, the procedure is described in an introductory clause or modifying phrase only, such as "Dew newly gathered and filtered through a clean Linnen cloth, though it be not very clear, is of yellowish color . . . (1:34). The procedure only serves to identify the dew. Only when directions are for practical use (and not, I emphasize, replication) are more detailed instructions given, though these are still vague by modern cookbook standards. Robert Boyle, for example, in volume 1, issue 15, appearing in mid-July, explains, for the benefit of sweltering Londoners, his new method for producing cold, useful for chilling drinks: "Take one pound of Sal Armoniack and about three Pints (or pounds) of Water, put the Salt into the liquors, and stir altogether, if your design be to produce an intense, though but a short coldness; or at two, three, or four several times, if you desire, that the produced coldness should rather last somewhat longer . . ." (1:256–57).

Even as early as the fifth volume, challenged by disagreements, authors demonstrate their experimental care and account for differences in results by describing in greater detail their experimental procedures and the conditions. Disagreements over experimental results on sap flow in sycamores lead Willoughby to consider both the date and weather conditions when the trees were bled. In volume 10, fear of challenge leads Robert Boyle to report that he took great care that a copper mixture was not shaken in the course of the experiment, although he himself does not believe that disturbance of the mixture to be of any consequence (10:468). The most explicit presentation of technique results from Francis Line's challenge of Isaac Newton's results. Newton in response lays out in much greater detail the method of his earlier experiment and the conditions under which the experiment occurred. He further suggests additional experiments and challenges Line to replicate them all. In presenting the method in such great detail, Newton insinuates that Line in doing his first set of experiments got things wrong. Since the debate is over whether such things as reported in Newton's account happen, the method and conditions to make them happen are crucial to the argument. (This incident and the surrounding story are examined more fully in chapter 4.)

By volume 30 authors claim they design experiments to meet specific objections of opponents. Desaguliers, for example, attempts to answer objections of the plenists that earlier experiments concerning bodies falling in vacuo were done over too short a distance. Desaguliers reports: "To obviate this I contriv'd a machine to this purpose, which consisted of a strong wooden frame . . ." (30:718). Variations in apparatus that might cause variations in results are also noted, to indicate that the author is not misled or confused by such variations (for example, 30:1078). Delicate parts of the procedures are noted, so as to distinguish the author's proper procedures from his opponent's less careful ones and to indicate specific points where the opposition may have erred. Desaguliers, for example, defending Newtonian optics at length against an extensive attack by John Rizzetti, points out many places where Rizzetti's procedures were misguided and where his judgment may have failed. In one instance Desaguliers comments, "This must have been Signior Rizzetti's mistake . . . for several of the Persons present at my Experiments made the same Mistake at first before they could perform the Experiment in manner above-mentioned; which they at last did. . . . This mistaking a Reflection for a Refraction has been the Occasion of several more Errors, and Difficulties to be met with in Signior Rizzetti's Book" (35:610).

Articles not engaged in overt contention continue to discuss method only sketchily. However, as experiments become incorporated into stories of discovery, the distinctions between trials become important as events in consciousness, so at least the crucial differences between trials become defined. Richard Watson, for example, introduces the sixth experiment of his series on the solution of salts with the comment: "Thinking that the difference in the bulks of the water before and after solution might be owing to the separation and escape of some volatile principle; I took care to balance as accurately as I could, water and sal gemmae, water, and the salt of tartar, water and vitriolated tartar &c . . ." (60:335). Since persuasion comes through the audience's willingness to accept the experimenter's experience of discovery, detailed accounts of method indicate both the experimenter's care and that he was convinced of his discoveries for good reasons.

Finally, in volumes 80 and 90, as articles present proofs of general hypotheses, the details of the experiments demonstrate care, exactness of results, relevance to thesis, and the elimination of alternatives. Henry, for example, gives a complex rationale for a particular method on the bases of precision and clarity of results:

> I employed the electric fluid, as an agent much preferable to artificial heat. This mode of operating enables us to confine accurately the gases submitted to experiment; the phaenomena that occur during the process may be distinctly observed; and the comparison of the products with the original gases, may be instituted with great exactness. The action of the electric fluid itself, as a decomponent, is extremely powerful; for it is capable of separating from each other, the constituent parts of water, of the nitric and sulfuric acids, of the volatile alkali, of nitrous gas, and of other several bodies, whose components are strongly united. (90:189)

William Herschel, in his experiments on the distinction between the visible and radiant spectrum, takes his measurements in several different configurations to prove that his results are caused by the principle he is trying to prove. Not only that, he rotates the position of the thermometers to ensure the results are not artifacts of faulty measuring devices. In such duplication and varying of measurements to ensure validity of results and to eliminate all other possible variables, Herschel presents his work in a way that approaches the modern concept of controls (90:255–326).

Indeed, throughout the period, the increasingly expressed awareness of possible variables seems to reach toward an unexpressed concept of controls. In recognizing differences of conditions or execution of the experiment that might affect results, the reports started comparing results from different situations. As more experiments report multiple trials with only slight variation of experiment, crucial factors are isolated. Then, as we have seen, multiple trials are explicitly designed to establish distinctions between two sets of conditions. The practice of experimental controls—running an experiment twice, identically except for an isolated crucial variable—is only the next step in argumentative clarity through the representation of method.

The changes in illustrations through the period also express the growing importance of methods. The early issues of the journal frequently illustrate the phenomena being reported on or new technological marvels, but rarely is the apparatus used for an experiment considered worth a picture. However, as experiments become more ingenious, elaborate, or just simply careful, illustrations follow. The first apparatus illustrations I found were in volume 25, showing the brushes and vacuum devices used by Hauksbee to generate static electricity in vacuum. Although not all experiments are illustrated with apparatus diagrams, they do become a prominent feature, as in Desaguliers's answer to Rizzetti, allowing the reader to visualize the experimental procedures and the results (35:575opp.). Herschel's articles in volume 90, punctuated by a number of quite realistic apparatus illustrations, give a concrete feel of what was done. The realism of illustration becomes particularly important as the account or story of the experiment becomes the reader's vicarious surrogate for the actual experiment, as will be discussed below.

Precision and Completeness of Results

As with method, results of the experiments are reported with increasing detail, care, and quantitativeness as the experiment bears more and more weight of argument, persuasion, and then proof. Early results are described vaguely and qualitatively, as though the phenomena of nature were robust, uniform, and self-evident. As disputes arise over reported results, writers become more careful about reporting what they see, and measurement takes a greater role. With the proliferation of quantitatively comparable results, experimenters begin puzzling over subtle variations in results; detailed results become a means of figuring out exactly what is going on. Finally, detailed quantitative experimental results, fitting quantitative theoretical results, form the empirical proof of general hypotheses.

In the early volumes, those experiments that provide directions for achieving certain wondrous effects have no explicit results at all, for it is simply assumed that following the recipe will lead to the desired effect. Where results are given they are in the form of general qualitative observations, such as in the example of luminous mackerel broth: "As soon as the Cooks hand was thrust into the water, it began to have a glimmering. . . . they who look'd on it at some distance, from the further end of another room, thought verily, it was the shining of the Moon through a Window upon a Vessel of Milk; and by brisker Circulation it seem'd to flame" (1:227). Even where quantification of results seems a rather simple matter, as in two experiments in volume 5 concerning expansion of a freezing solution and the timing of respiration, the results were given in purely qualitative terms.

Again, debate and conflict push results to greater detail and precision in exactly the same articles with more detailed accounts of method. Newton, for example, in answering Line, spends a lengthy paragraph describing the three different images cast by a prism, distinguishing the character of these different images, so that anyone repeating the experiment can find the oblong image which was Newton's particular concern and which Line disputed (10:503).

By volumes 15 and 20 quantitative results in measurements of the speed of sound, barometric air pressure, and specific gravity enable comparisons. With the increase of multiple trials, distinctions among results of various trials become a practical expository tool. In volume 50, for example, William Lewis, in investigating mixtures of platinum and gold, creates nine different mixtures of different proportions from 1:1 to 1:95 in order to compare both qualitative and quantitative properties (50:148–55).

By volume 60 the results sought and reported have specific relation to the hypotheses being investigated and tested. James Johnstone reports a series of experiments designed to test hypotheses concerning the function of nerve ganglions; not only are the results found consistent with the hypotheses, but he adds results from experiments reported by other authors. These additional results also support the hypotheses, even though the experimenters did not have the same questions in mind; Johnstone was already aware of the potential for bias in experimental design (60:30–35).

Near the end of the eighteenth century, as arguments move toward proof, the precise reporting of results enable them to be compared to quantitative predictions of hypotheses and thus to serve as direct evidence. Herschel, in volume 90, in order to prove that the radiant heat is distinct from the visible spectrum, provides extensive quantitative results, to the point of inductive tedium (90:255–322).

The Ocular Proof and Communal Validation

The increasing precision and detail of method and result accompanies a major change in how accessible the experimental demonstrations are for the readers of the journal. As the actual experiment becomes more of a private affair for the investigator and close associates, verisimilitude of the report reassures the readers that the events happened, and happened in the way reported.

In the early years many of the experiments reported in the *Transactions* were demonstrated before the assembled body of the Royal Society at regular meetings. The demonstration is its own meaning, for all to witness and agree it did take place. The report of the experiment is little more than a news report that such an event took place and was witnessed by the assembled body. The validity of events rests on the communal witness and not the story told.

The communal witness remains important validation of the experimental events for much of the earlier part of the period, but as experiments gain subtlety and face conflicting results, experimenters need to control the particular conditions of demonstration. Experiments stay in the laboratory, remote from the lecture hall. Designated competent witnesses travel to the experiment to represent the general membership and a prestigious list of witnesses becomes an important feature of the report. Thus in volume 30 Desaguliers's witnesses include the king and queen as well as the chief members of the Royal Society. Witnesses, however, no matter how prestigious, can always be opposed by equally impressive witnesses who attest to conflicting results, so a precise account of methodology with detailed results, allowing critique, comparison, and replication become part of the argument.

The next change occurs when the problem shifts from the simple existence of phenomena to the meaning of baffling, troublesome phenomena. The experiment, no longer an end in itself, certainly no longer performed in public, becomes a private affair, an event in the individual intellectual journey of the investigator. In the volumes 40 onward there is almost no direct conflict over results, but rather only over theories, and even the theories are presented more as the results of individual research programs rather than highly combative claims and counterclaims. Conflicts and comparisons of results are more likely to occur within the series of experiments of a single scientist trying to work out the subtleties of a complex phenomenon. The series of experiments are not presented as being likely to be replicated. For example, Tiberius Cavallo in volume 70 reports his earlier experiments as part of his puzzling through a problem in electricity, not giving adequate instructions for replication, but at the end he does give detailed replication instructions for one final, contrived experiment so others can convince themselves of his conclusions and can explore the phenomenon further (70:15–29).

Nonetheless, specificity, detail, and plausibility of the experiments are important as part of the story of the intellectual journey of the investigator. Since neither the reader nor any surrogates or representatives, except for the author himself, has witnessed the series of experiments, the account must stand in place of the witness. The reader in order to understand the experimental argument must vicariously witness the experiment through the account. In order to earn the trust of the reader, the story of the experiments must be told plausibly if not persuasively, and the events reported on must provide sufficiently good cause for the investigator to come to the conclusions he reports.

When finally the structure of the series of experiments turns from a representative personal journey to a retrospective guided tour of conclusions and experimental evidence, the account of the experiment has come, at least for the time being, to stand as the proof. In the long run, the experiment or series of experiments may be replicated, but in the persuasive experience of the reading of the argument, the story of the experiment must serve as a surrogate for the actual experiment.[5] By this time papers were read to the Royal Society, but experiments were conducted in private, simply to be reported on.

Organization of the Articles

The organization of the experimental articles serves as an outward manifestation of all the trends discussed to this point. Articles tend to grow longer throughout the period as the argument surrounding the experiment grows and individual investigations rely more and more on series of logically connected experiments rather than single events.

In the first issues most of the information passes through the voice of the editor who simply reports on things he has found out about from a variety of sources. Typically, Oldenburg announces that, "The Ingenious Mr. Hook, did, some months since, intimate to a friend of his, that he had . . ." (1:3). By the end of the first volume authored articles appear, with much the format that would maintain through volume 25. The article opens with a short statement of what was done, followed by a narrative of results. Often articles end there, although some discussion of

5. Steven Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," reports that a number of the features of virtual representation that did not appear regularly in journals until the second half of the eighteenth century were mobilized in books by Robert Boyle almost a century earlier. This uncoordinated development of book and journal publication raises two questions. First, are the dynamics, constraints, form, and literary situation of book publication significantly different than that of journal publication, so as to encourage the emergence of different textual features at any particular time or to cause any one common feature to emerge at different times? Second, what are the formal interplay and mutual influence of journals and books? Chapter 4 begins an investigation of such questions.

Chapter 2 of Shapin and Schaffer, *The Leviathan and the Air-Pump*, offers a more complete view of the proper form of communal knowledge and the importance of empirical experience, direct and virtual, for successful public debate and evaluation of knowledge claims. Much of Boyle's attitude toward empiricism and public debate seems to have been carried out in the history of the rhetoric of the *Transactions* analyzed in this chapter.

cause or meaning may follow. Articles tend to be short, often only a page or two, and usually discuss only a single experiment or trial.

In those articles reporting on a series of experiments, however, continuity does increase over this early period. At first experiments in a series are only loosely connected, being concerned with the same general phenomenon, as in the many series of experiments putting different objects in vacuum reported on in volumes 5 and 10 or as called for in William Petty's "Miscellanious Catalogue of Mean, vulgar, cheap and simple Experiments," all loosely related to weights and specific gravities (15:849–53). Occasionally a rationale explains specific trials, as when Boyle provides reasons for choosing particular animals to deprive of air: the duck, which breathes in air and dives; the viper which has lungs but is coldblooded; a newborn kitten, recently in the womb without access to the atmosphere, etc. (5:2011–31, 2035–56). A result in an early experiment in the series may lead to new questions to be explored in later trials, such as when a Captain Hall notes that a rattlesnake is less lethal on successive bites; unfortunately, the experimental program was cut short when neighbors began complaining about missing dogs (35:309–15).

As experiments begin to respond to conflicts, their reports focus on the issue in contention. Typically, the report starts with a statement of the phenomenon in dispute and then a discussion of the opponent's work or position. The author's own position with consequent experimental method and supporting results follow, with perhaps some general conclusions, as in Desaguliers's article arguing with Leibniz' explanation of barometric fall in wet weather (30:570–79). By volume 40, the hypothesis or meaning of an experiment often precedes the account of the experiment, even where no particular issue is in contention. Desaguliers, for example, not only begins a paper on statics with a general proposition, but he promises to provide elsewhere a more general theory (40:62–69).

As phenomena are treated as more problematic, articles take on a different organization, opening with an introduction to the problematic phenomenon, often substantiated with the story of an experiment that did not go as expected. With the problem established, the article chronologically describes a series of experiments aimed at getting to the bottom of the mystery. Transitions between pairs of experiments draw conclusions from the previous experiment and point to the rationale or need for the consequent one. In the process of continuous reasoning, the experimenter gradually comes to an adequate understanding of the phenomenon, which is pulled together in a concluding synthesis or explanation of the phenomenon, as in William Hewson's investigations into the nature of blood (60:368–83).

At the end of the period, articles using experiments to prove general claims often begin with philosophic statements about general knowledge. Then a problem is presented, either through a surprising experimental result or through the exposition of a gap in current knowledge. Then a series of claims resolve the problem, followed by supporting experiments. Although a subseries of experiments may be presented chronologically, the larger structure of the article is based on the logical order of the claims to be proved. The conclusion may discuss consequences of these claims, but no synthetic set of conclusions is needed because the claims have already been presented at the beginning. Henry's investigation of muriatic acid (90:188–203) and Herschel's investigations of radiant heat (90:239–326) conform to this general pattern.

Forging Persuasive Forms and a Collective Literature

One early article (15:856–59) that in many respects resembles articles from a century later reveals the rhetorical function of the features of the experimental article that emerge by 1800. The anonymous article starts with a general proposition concerning the ease with which larger wheels may be drawn over an obstacle. The experiment, clearly designed as a demonstration of that proposition, is presented in great quantitative detail, as are the results. Moreover, many different trials are set out, isolating variables and allowing exact comparisons proving the general proposition. However, the theoretical point was already well established in the literature (it is attributed to three authors, both ancient and contemporary) and this experiment and the article reporting it are only to convince practical people—wagonmakers and wagon purchasers—of the advantages of what was already known theoretically. The point is not to prove the truth of the statement, but to persuade recalcitrant craftsmen to use a well-established truth.

In those early years, argumentative persuasion could be used for the ignorant artisan, but for those actively pursuing nature, nature was portrayed as speaking for herself. The scientific report was simply a matter of news. Just as an earthquake or passage of a meteor needed to be reported, so did experiments. Not until nature was treated as a matter of contention and then a puzzle could the experiment become part of an argument and could theory or claims hierarchically and intellectually dominate experiments.

With the journal serving as a forum, contention grows. This contention pushes the individual author into recognizing that he is not simply reporting the self-evident truth of events, but rather is telling a story that can be questioned and that has a meaning which itself can be mooted. The most significant task becomes to present that meaning and persuade others of it. Persuasion of claims then lies in a story of personal discovery, supported by good reasons and careful work. Since all people, however, have good reasons, the persuasive story must shift to more universal grounds: the proof of a claim transcending the particulars of an investigation.

To draw the historical lines even more sharply, we observe four loose and overlapping stages in the development of the experimental report. In the first stage, most evident through volume 20 (c. 1665–1700), articles consisted of uncontested reports of events. In the second stage, most evident from volumes 20 through 50 (c. 1700–1760), experimental articles tended to argue over results. Beginning in about volume 50 through volume 70 (c. 1760–1780), articles explored the meaning of unusual events through discovery accounts. Finally, in volumes 80 and 90 (1790 and 1800), experimental articles offered claims and experimental proofs.

In this process we find the beginnings of something like Karl Popper's third world of claims, separate from both nature and the individuals who perceive it. The earliest reports—accounts of what happened, as witnessed by many—recognize only the first world of nature. Contention draws attention to the second world of human perception and consciousness, throwing the authors back on to their own experience and thought (although hedged with the proper respect for nature and empirical methods) as the essence of their reports. Finally the claim or conclusion—Popper's third world—becomes the central item to be constructed within the article, to be supported by empirical evidence from the first world and proper method and reasoning from the second world.

Yet to the end of the period, experimenters present their claims as purely products of their individual interactions with nature, not explicitly recognizing the communal project of constructing a world of claims. In most of the articles the literature is still not treated in any explicitly codified way, as we have become familiar with in the twentieth century. The experiment still appears solely the result of the individual's invention and understanding. Although the individual scientist has an interest in convincing readers of a particular set of claims, he does not yet explicitly acknowledge the exact placement of the claims in a larger framework of claims representing the shared knowledge of the discipline. Herschel does not relate his theories and findings to a large body of knowledge other than his own, except in the most general way. He presents himself as the only explorer of his terrain and the experiments are thus the confirmation of the general truths he has discovered in his particular travels. The only consistent use of other literature occurs in debates where discussion of the literature serves to draw lines and marshal forces rather than construct an edifice beyond the immediate claims.

Although the collective intelligence of the scientific community before 1800 is not regularly displayed in explicit codifications of the literature, the collective intelligence is embodied in the way the members of the community have chosen to communicate with one another. Whether the emergence of an argumentative community necessitated a conventional genre in which to carry on that argument or whether the clarification of forms of argument allowed a coherent community to coalesce in discussion is an unanswerable dialectical conundrum. A more exact formulation might be that a community constitutes itself in developing its modes of regular discourse.

In this particular case, the kind of argument the community engaged in, over the regular appearances of natural phenomena, seemed best pursued by increasing descriptive detail and precision, re-creating events increasingly designed to display particular features of that nature. But regularity and particularity proved at odds, creating new problems in symbolizing nature. Particular and general formulations did not always fit together easily, so new modes of discourse were needed to expose the regularities hidden in the anomalous particulars and to demonstrate that general formulations offered precise representations of particulars. The emerging form of experimental report offered a way to harness stories of the smaller world of the laboratory to general claims about the regularities of the larger world of nature. In the attempt to satisfy the objections and desires of the growing scientific community, the experimental report kept changing in form, as it continues to do today—for objections and desires grow with the ability to formulate them. And what is a science without objections and desires?