S|S|S

ABSTRACT This paper compares the argumentative practices of the English and French scientific communities from the origin of the scientific journal in 1665 up to 1700. To that end, we ask a uniform set of questions related to argumentative practice in a large sample of articles randomly drawn from the three pre-eminent scientific journals of this period: *Philosophical Transactions* of the Royal Society of London, *Journal des Sçavans* and *Mémoires de l'Académie Royale des Sciences*. The results suggest an interesting link between socio-political structures and their influence on early scientific societies, and the articles in their fledgling publications. In particular, the early professionalization of French science through the Académie Royale led to a heightened emphasis on features familiar in 20th-century practice: quantification, mathematical and mechanical explanations for acquired facts, visual representations of facts and their explanations, and use of observations and experimental results as stepping stones to theory. This social arrangement led as well to a narrower view of what constituted acceptable subject matter. Despite these differences, there are also enough similarities in English and French communicative practices to suggest the beginnings of an international scientific community.

Keywords hedging, quantification, rhetoric of science, scientific societies, visuals

Argument and 17th-Century Science:

A Rhetorical Analysis with Sociological Implications

Alan G. Gross, Joseph E. Harmon and Michael S. Reidy

It is now over two decades since Bruno Latour and Steve Woolgar set up their tent amid the inhabitants of the Salk Institute, La Jolla, California: 'a strange tribe who spend the greatest part of their day coding, marking, altering, correcting, reading, and writing'.[1] Part anthropology, part sociology and part rhetorical analysis, their *Laboratory Life* vividly portrayed how social interactions enter into the making of 'literary inscriptions' the authors hope will enter the domain of accepted knowledge among their peers.[2] Since then, many other studies have demonstrated that rhetorical analysis can lead to conclusions relevant to the sociology of science.[3] We believe that as rhetoric becomes even further integrated as a method within the sociology of scientific knowledge, more uses will be found for it and, as a result, scientific communities will more often be seen as communities whose communicative and persuasive practices constitute necessary conditions to the creation of new knowledge.

Social Studies of Science 30/3(June 2000) 371–96

[0306-3127(200006)30:3;371–396;014309]

To add some weight to this general case, we have examined the argumentative practices of the three key periodicals reporting 17th-century science: the *Philosophical Transactions*, *Journal des Sçavans* and *Mémoires de l'Académie Royale des Sciences*. These three have an important common social bond: each has some connection with a scientific society – the Royal Society of London for *Philosophical Transactions* and the Académie Royale des Sciences of Paris for both the *Journal des Sçavans* and *Mémoires*. These neophyte organizations had within their ranks most of the authors, readers and journal editors of 17th-century science. They also created the social networks needed to establish what constituted acceptable argumentative practices in science.[4]

No two groups founded at nearly the same time with similar interests could be more different in organization and constituency than the Royal Society and the Académie Royale.[5] The Royal Society was a fairly large, loose-knit group of amateurs and 'natural philosophers' in and around London – some extraordinarily talented, some with nothing more extraordinary than an above-average curiosity about the natural world. They met regularly to learn about and discuss the latest experiments and observations, as well as to witness demonstrations of them. The Society received the blessing of the reigning monarch, Charles II, but depended largely upon members' dues and generosity for its economic survival.[6] The Royal Society secretary, Henry Oldenburg, launched *Philosophical Transactions* in March 1665 as a private venture. His transactions reported on technical news from home and abroad, often sent to him in the form of letters from his many correspondents.[7]

In contrast to the Royal Society, the Académie Royale was closer to what we think of today as a government-funded research institute. Science was the principal occupation of its members, who lived and worked together in Paris under the patronage of Louis XIV, funded 'at a level similar to the annual income of the wealthiest monastery in France'.[8] The Académie was also deeply involved in the publication of the fruits of its members' labours under the Imprimerie Royale. During the 17th century, it published two handsome volumes on plants and animals, as well as a large collection of articles on mathematics and physical science, by 'messieurs de l'Académie Royale'. The first scientific 'mémoires' of the Académie Royale date from 1666, but most of these were not actually published until the early 18th century – in the multivolume *Mémoires de l'Académie Royale des Sciences, depuis 1666 jusqu'à 1699*. However, articles by Académie members and summaries of their research did regularly appear throughout the 17th century in *Journal des Sçavans*, started privately in January 1665 by Denis de Sallo.

Joseph Ben-David captured a key social difference between these two early scientific societies:

> [W]hereas the Royal Society was an independent corporation based on membership including amateurs and politicians of science as well as scientists of outstanding accomplishments, the *Académie* was a sort of

> elevated civil service composed of only a small number of scientists of high reputation.

Importantly, the French arrangement had as its purpose

> ... to control science and limit its influence ... [T]he empirical and experimental approach of science [was not to be] diffused to politics ... the norms of universalism of science [were not to be] applied to matters of religion and social estate.[9]

These social differences also had, as we hope to demonstrate, consequences that affected argumentative practices as manifested in the concrete utterances found in journal articles.

Methodological Considerations

Others have conducted studies of early scientific prose by a close reading of articles and books by historically significant scientists like Boyle,[10] Newton,[11] and von Guericke,[12] or by an analysis of a selection of *Philosophical Transactions* articles.[13] To our knowledge, however, none has attempted systematically to compare the communicative practices of the two centres of 17th-century science, England and France, using a sample of broad scope.[14] Our object of study for this purpose is the scientific journal article, a genre of discourse that originated independently in England and France during the year 1665.

In our view, one of the methodological weaknesses of past rhetorically-informed analyses of scientific texts has been: how does one know whether the insights into scientific communication represent anything more than the possibly idiosyncratic characteristics of particular authors? Moreover, how does one know whether emphasis on a distinctive rhetorical feature or two doesn't leave the reader with a distorted impression of the scientific literature as a whole? For example, much has been made of the epistolary strains of the early articles in the *Philosophical Transactions*, as manifested by the occasional opening of 'Dear Sir' and the rare tidbits of extraneous personal information. Yet our own impression is that the typical scientific articles in other early scientific journals little resemble what one normally thinks of as a 'letter'.[15]

As a first step toward overcoming such limitations, we have attempted what we hope will prove to be a more systematic approach to a rhetorically-informed analysis. Our approach has three main components: guided by past studies on the rhetoric and history of science, we start by assembling a well-motivated set of questions relevant to scientific argument in the 17th century; then we ask these questions of a large, representative sampling of texts from three journals; finally, we tabulate and interpret the results, and infer from them our explanation of their possible sociological implications.

Consistent with the spirit of Chaïm Perelman and Lucie Olbrechts-Tyteca's *The New Rhetoric*,[16] we define argument broadly as the ensemble of means that authors employ to make and support their assertions. In particular, we concentrate on how scientists employ argument to establish new facts about the material universe and offer explanations for them. We propose four topics as central to understanding scientific argument in the 17th century. These topics are based on what we take to be a consensus among scholars who have dealt with scientific communication in the 17th century.[17] While other taxonomies are possible, we take ours as at least plausible:[18]

1. What makes an observation or an experimental result a scientific fact? In the 17th century, there were at least two standards according to which facts were judged scientific. First, a scientific fact was an occurrence in the natural world that was reported by a reliable individual – usually a member of a scientific society – and was witnessed by one or more such observers. Second, a scientific fact was a finding resulting from the appropriate use of instruments (telescope, microscope, thermometer, air-pump, and the like) combined with methods discussed in item 2.
2. How are the facts generated? Whether the 17th or 20th century, there are several basic means: observation of objects and events in natural settings; manipulation of natural and man-made objects in artificial settings for experimental purposes; computation or description based on theory; or some combination of these. The fact-generating enterprise of science also entails developing new methods and equipment for improving observations, conducting experiments, and confirming or extending theoretically based assertions.
3. What is the relationship between scientific facts and scientific explanations? In the 17th century, not all scientists were concerned with explanation; many were content with collecting and ordering facts about nature. Scientists interested in explanation, however, realized that their explanatory conjectures must square reasonably well with the facts defined according to item 1.
4. What sorts of explanation are there? For 17th-century scientists there were two kinds of explanation, both causal: mechanical and mathematical. Sometimes mechanical causes were directly observable. Sometimes they were observable only by their effects. In that case, plausible reconstruction was necessary. But causes might also take the mathematical form of universal laws. These would have a mathematical expression, consistent with the Galilean programme: $f = ma$, for example.

In the remainder of this paper we will illustrate these topics and the range of arguments they generate. We consider not only written arguments but visual contributions to argument as well. As part of this discussion, we also examine how 17th-century scientists employed textual features known to be of argumentative importance to the modern scientific article: 'hedging',[19] and quantitative statements.[20]

To gather a representative sample for analysis, we randomly selected 100 whole articles from the three most significant journals reporting 17th-century science, as determined by Robert Gascoigne: *Philosophical*

Transactions, *Journal des Sçavans* and *Mémoires de l'Académie Royale des Sciences*.[21] For the analysis of hedging and quantitative statements, we gathered ten-line passages randomly selected from 200 articles in the same three journals. We divided the articles and passages equally among the English and French.

We anticipated that tabulating the answers to our questions would provide us with an empirical foundation upon which to erect plausible generalizations about the argumentative practices of the English and French scientific communities in the process of formation. We make no pretence of having isolated all the argumentative features of the 17th-century scientific article, or of having entirely avoided arbitrariness in our questions, or of avoiding some subjectivity in our application of them. We are confident, nevertheless, that our method yields conclusions sound enough for confirmation or refutation about the general state of scientific argument in the various scientific disciplines, and in the English and French communities out of which modern science emerged. (For ease of reading, we have translated all the French passages quoted below into English.)

Arguing the Facts into Place

In reading the English and French articles in our sample, one is immediately struck by the *miscellanea curiosa* of new facts about the natural world and its workings. Monsieur de la Voye reports on little worms that eat stone (1666–MAS010; also in 1676–PT082).[22] Lister speculates on the existence of veins in all kinds of plants (1672–PT063). Méry describes the physiology of a pelican (1693–MAS084). Homberg reports on why leaf-like crystals formed in a flask full of antimony and rainwater (1693–MAS075), and also on how he was able to distil phosphorus from urine (1692–MAS009). Halley calculates the life expectancy in the city of Breslaw (1693–PT041). Henshaw offers 'some observations and experiments upon may-dew' (1665–PT102). La Hire witnesses and measures the progress of an eclipse of the moon on 28 July 1692 (1692–MAS045). Hooke provides instruction on how to 'make the picture of any thing appear on a wall, cub-board or within a picture-frame' (1668–PT006). Cassini observes through his telescope 'a precise conjunction of a satellite of the planet Saturn with a fixed star' (1692–MAS074).

The data for genre in Table 1 indicate that observation is by far the favourite means of establishing new facts in our 100-article sample. About half this sample presents observational facts exclusively, or observational facts buttressed by some theoretical discussion. Also noteworthy in Table 1 is that of the 71 observational and experimental articles, more than half offer new facts without any theoretical discussion. We know from Steven Shapin and Simon Schaffer that English authors from the 17th century, particularly Robert Boyle, 'offered the matter of fact as the foundation of proper knowledge'.[23] The animating philosophy behind this approach is that theories come and go and are constantly being revised and expanded;

TABLE 1
Genre and Purpose in Sample of 100 Whole Articles

	French		English	
	No.[a]	%	No.[a]	%
Genre				
Experimental	5	10	6	11
Theoretical	6	12	10	19
Methodological	3	6	5	9
Observational	10	20	20	38
Observational/Theoretical	18	35	7	13
Experimental/Theoretical	4	8	1	2
Mathematical	5	10	3	6
Other	0	0	1	2
Main Purpose				
Observation	11	21	19	36
Experimental Results	5	10	8	15
Mechanical Explanation	19	36	14	27
Mathematical Rule	6	12	2	4
Mathematical Explanation	10	19	3	6
Making or Improving Equipment	1	2	2	4
Other	2	4	4	8

[a] As the categories are not completely exclusive, totals add up to more than 50.

facts 'mirror nature'. For that reason, early researchers like Boyle offered theoretical explanations of their observational and experimental 'facts' only with extreme caution.

This orientation toward observed particulars, however, does not mean that theory is anathema in the 17th-century article. The data in Table 1 show that 54 of the 100 articles possess some theoretical or mathematical discussion. This interest in the abstract and conceptual appears to be greater in the French than in the English. True, in our sample, the English were as likely as the French to compose purely theoretical or mathematical articles (13 and 11 articles, respectively). Nevertheless, in the English sample, only 8 articles moved from observation or experiment to theory, while in the French sample, 22 articles did so.

Whatever the means of establishing facts, English and French scientists are both concerned about the warrant for them. Clearly, they must meet a higher standard than the opinions and observations of everyday life, if only because authors know that their statements will likely receive scrutiny and judgement by an international group of readers with similar interests.[24] In deference to this standard, we know from Myers and others that modern scientists hedge.[25] A simple textual feature, barely noticeable to the uninitiated, 'hedging' is their indication that the quality of evidence is being carefully weighed. This feature is present but not prominent in 17th-century scientific prose. As evidence for this claim, we found relatively few hedges in our 200 short passages: averages of 0.13 per hundred words for the French, 0.21 per hundred words for the English,[26] an appropriately small amount for narratives relying heavily upon personal observations as well as mathematical calculation.[27] Typical are assertive sentences without qualifications, such as: 'The species of corals and of *Madrepora*, the mushrooms of the sea, the *Tubularia marina, rubra IB* are also as hard as stones' (1700–MAS040), and 'In this equation no more is needed than the substitution of the values of v & of dz, which will result in x & in dx of the equations of the given curves *AHG* & *AFK*; & will become that of the curve we are looking for, *BC*' (1699–MAS067).

Despite the low counts for hedging, we found many interesting varieties of 17th-century scientific hedging populating select passages from our sample. In this heavily hedged passage from *Philosophical Transactions* on the existence of veins in all kinds of plants, for example, Martin Lister leaves no doubt that he is speculating about the ramifications of his collected facts (hedges in bold):

> That **though we seem to be more certain** of the ramifications of the Fibres, wherein those veins are, **we yet are not so**, that those veins do any where grow less and smaller, **though probably it may be so**. That which makes us **doubt** it, is the exceeding smallness of these veins already, even where we might **probably expect** them to be Trunk veins and of the largest size; and being there also in very great Numbers and running in direct lines along the fibre, we **guess**, that one or more of them **may be** distributed and fall off on either hand with the subdivisions of the fibres, and not suffer any diminution in their bulk. (1672–PT063)

In a French passage, Méry uses hedges to dramatize the tension the scientist feels between the doubt he must always entertain and the relative certainty he can occasionally attain and enunciate:

> One **cannot doubt** that the small muscles that are attached to the feathers of the skin of the body of the pelican serve to move them in different directions, & that when they move, one after the other, they can make the feathers move in circles. It **certainly looks as if** the fleshy fibres of the down can also create the same movements.
>
> Mr Méry was not, in the pelican he dissected in 1686, looking for the place from which the air came that filled the cells of the skin, but in 1692 he dissected yet another, in which he viewed it in a manner that **fully satisfied him**. (1693–MAS084)

In the French sample, unlike the English, doubt has been expanded to include a set of concerns that focus on instrumental limitations, including that oldest of instruments, the human eye. While Méry's passage on animal physiology parallels Lister's, there is no English parallel in our sample for the following passage of Cassini's, which makes the limitations of naked-eye observations its subject. Cassini's is a second-order scepticism not found in the English sample. Cassini does not merely use hedges; he reflects on hedging:

> Scarcely does one find four or five observations of these conjunctions among all those that have been preserved since the beginnings of astronomy up to the present century: even so there is room to doubt whether

> these four or five apparent conjunctions, **since they were observed only with the naked eye**, are really precise and without any interval. For we now know that, because of light rays that increase the apparent size of the stars, **there are conjunctions that appear to be precise, although they may be nothing of the sort**; the use of telescopes having forced us to recognize that there are considerable intervals between stars that appear to the naked eye to be so completely conjoint that they seem one and the same star. (1692–MAS080)

For English scientists, the warrant for facts seems more a matter of reliable testimony than of precise measurement. In the following English passage on a medical curiosity, scientific evidence is viewed exactly as forensic evidence would be, the absence of hedges being implicitly justified by the presence of sworn testimony:

> We, the Physicians under-named, do hereby certify, that all the particulars of the Chirurgical operation of extracting the Bodkin out of the Bladder of *Dorcas Blake*, as contained in the foregoing account, are truly and faithfully related, it being perform'd by Mr *Thomas Proby*, Master Chirurgeon, with great skill and success in our presence, as witness our Hands, this 22d of *May*, 1695.
>
> *I. Madden* Presid. *T. Molyneux.*
> *Wm. Smith.*
>
> *Dorcas Blake*, of *Fishamble-street*, in the Parish of *St John* [,] *Spinster*, came this day before me, and being sworn on the holy Evangelists, saith that the above relation is true in substance, and that she did swallow the Bodkin therein mentioned, and that the Bodkin now shewed to her is the same that she formerly swallow'd.
>
> her
> *Dorcas* **X** *Blake*
> mark.
>
> *Jurat coram me decimo die Junii* 1695.
>
> G. Blackall *Major. Dublin.*
> (It is sworn in my presence, 10 June, 1695
> G. Blackall, Sr., Dublin) (1700–PT110)

In 17th-century science, it was at least an occasional practice to lend credibility to reported facts by mentioning witnesses. In our sample of 100 whole articles, this practice occurs in articles reporting some unusual observation or especially important experimental results, and appears to be more characteristic of the English than the French. In the English sample there are five articles citing witnesses: two experiments with animals (1667–PT003 and 1696–PT014), one physics experiment by Boyle (1676–PT021), one trial at Court involving some medication for coagulating blood (1673–PT034), and one monstrous birth (1670–PT038). Only two French articles mention witnesses: a joint observation by a group of astronomers (1677–JS042) and an experimental series with an English connection (1672–JS006) – namely, the article had been read at a Royal Society meeting. This stronger reliance on personal testimony is indicated in English scientific prose through an orientation toward human relationships largely absent in the French: witnesses are sworn, observers of experiments are named, readers are invited to repeat experiments. An orientation toward readers is also embodied in expressions that 'humanize' the prose to the detriment of its objective stance. When a Fellow of the Royal Society says, 'I shall premise some Experiments made many years ago which perhaps may give no less satisfaction unto many of our Experimental Philosophers than they afforded me, when I first made mine' (1674–PT072), he is deferring to his colleagues' own past experiences with conducting and witnessing experiments, not expressing doubt.

We depart here briefly from our random sample to address an argument topic of 20th-century science that seems to be largely absent from its 17th-century ancestor: replicability as a check on experimental or observational quality and reliability. We do not mean that experiments and observations are not repeated or contested. In the case of the controversy surrounding Newton's first scientific article (1672) – reporting the optics experiments he carried out in his darkened chamber with a glass prism – the durability of purported facts as indexed by the repetition of experiments is clearly an important topic of argument.[28] But while Robert Hooke and Christiaan Huygens challenged Newton's theoretical interpretation of his experimental results, neither questioned the results themselves. It was not until the letters from Francis Hall (also known as Linus, a Jesuit professor at the English College in Liège) arrived in 1674, that the experiments were even performed at the Royal Society, the 'house of experiments'. Even in this case, the issue was less the durability of purported facts than the official witnessing of Newton's experiments by other Society fellows. In the *Opticks* of 1704 (a work just past our period), Newton, in enjoining his readers to repeat experiments, is encouraging them, not to check, but to see for themselves. The case of Huygens' replication of some of Boyle's experiments with an air-pump, recounted by Shapin and Schaffer, is closer to the modern standard: but it seems to be a notable exception to the rather casual rule; as Shapin and Schaffer note,

> ... even the notion of *verification* itself is profoundly problematic. The Florentines [Accademia del Cimento in Italy] announced that they had verified Boyle's results without needing Boyle's machine.[29]

Historian Alan Shapiro summarizes what we take to be the most accurate view:

> The very concept of rigorous and public replication, which is often considered to play a central role in modern science ... was by no means a standard feature of seventeenth and early eighteenth century science ... [T]he experimental tests of Newton's theory were private, casual, and, by later standards, rather lax in what they took to be either confirmation or refutation.[30]

Arguing Explanations into Place

Our English and French samples differ not only in their manner of establishing new facts but also in their interest in explaining these facts. In our sample of English articles, 20 made observational claims detached from any apparent explanation and 6, experimental claims detached from any apparent explanation. In the French sample, 10 articles made only observational claims and 5, only experimental claims. So we tallied 26 factual claims independent of causal explanation for the English, but only 15 for the French sample (see Table 1).

These bare numbers hint at the differing scientific practices and concerns in each country, but they do not give a firm sense of the flavour of two sorts of 17th-century scientific argument, one presenting new facts, the other providing an explanation for them. To illustrate this difference, we selected two articles: Thomas Henshaw's '*Some Observations and Experiments upon* May-Dew' and 'Extract from a Letter of Mr. Huygens, touching the Phenomena of Water from which all Air has been Removed'. In the first case, Henshaw subjects May-dew (dew gathered in May and supposed to have medicinal and cosmetic properties) to a series of trials designed, apparently, to ascertain the conditions under which it will putrefy. We say 'apparently' because this general purpose is nowhere stated; it must be inferred from a series of loosely connected experiments narrated in no discernible order. The series leads to no conclusion and is preceded by a narrative introduction, not about Henshaw's experiments, but about Henshaw himself, presumably written by the editor of *Philosophical Transactions*:

> That ingenious and inquisitive Gentleman, Master *Thomas Henshaw*, having had occasion to make use of a great quantity of *May-dew*, did, by several casual Essayes on that Subject, make the following Observations and Tryals, and present them to the *Royal Society*. (1665–PT102)

Henshaw's experiments are reported in a lively, novelistic manner, a mode of representation that leaves their larger purpose unclear. Here's a single sentence vividly weaving together method and results, but offering little in the way of explanation:

> That having several Tubs with good quantity of *Dew* in them, set to putrefy in the manner abovesaid, and comming to pour out of one of them to make use of it, He found in the water a great bunch, bigger than his fist, of those Insects commonly called *Hog-lice* or *Millepedes*, tangled together by their long tailes, one of which came out of every one of their bodies, about the bigness of a Horsehair: The Insects did all live and move after they were taken out. (1665–PT102)

In contrast, Huygens' focus is explanation. His *Journal des Sçavans* article has three main components: a theoretical introduction that motivates his investigation; a series of experiments designed specifically to answer the theoretical question he poses; and a conclusion that ponders the theoretical impact of his results. His introduction follows the essentials of 20th-century practice.[31] He stakes out an intellectual territory – one of Boyle's research programmes – and establishes his niche within it:

> Before communicating to you what I have observed concerning the suspension of water in a vacuum, I want to repeat the experiments, in order to verify the remarks I made at another time and in order to attempt to penetrate to the causes of an effect so surprising. I will first relate my observations and then I will pass to the conjectures I have made to account for them.
>
> The experiments that the illustrious Mr. Boyle performed one day in 1661, with the description of the pneumatic pump, gave me a starting point for examining the matter at hand. In one of these experiments, Boyle put a four-foot glass tube, full of water, in a container or vessel from which the air had been evacuated, the open end of the tube being submerged in another quantity of water, contained in a glass. The air from the container having been evacuated as far as was possible by means of his pump, the water of the tube flowed down into the glass up to the point at which no more than about one foot remained, all the rest of the tube remaining empty of water and of air. He judged with good reason that this height of one foot of water that stayed above the level of that in which the open end of the tube submerged, remained suspended because there remained in the container a bit of air that the pump, being defective in that respect, could not evacuate. (1672–JS006)

In the article itself, Huygens occupies the niche his criticism of Boyle creates, providing the reader with a new theory to explain his novel results. In so doing, Huygens challenges Boyle's reasonable inference by completing and reporting on a series of six experiments, each carefully described. Having depicted his apparatus, he launches into a narration about the trustworthiness of his method, a narration that is also a part of his argument:

> But at the end of the month of December in the same year, 1661, having left this water in the vacuum for twenty-four hours (which completely purged it of the bubbles it gives out when fresh water is used) & having filled the vial *C*, I was surprised to see that notwithstanding that I had tried very hard to remove the air from vessel *B*, the water did not descend at all from *C*, which remained perfectly full; I could hardly suspect that there had been any defect in my pump, nor that the vessel *B* was badly blocked; but to be perfectly clear about this, I removed the vial *C* from underneath the vessel and after having forced in a small air bubble, I replaced it as before; and having worked the pump, I saw that in the end all the water descended very nearly up to the level of that of glass *D*. That assured me that there had been no defect in the pump, and that the water purged of air remained suspended without descending, although the vessel *B* was completely void of air, or at least as much of it as it was when the fresh water descended from the vial. I made the water descend a second time by inserting into the neck of the vial a bubble so small that it was hardly visible. (1672–JS006)

After describing in detail the six interlocking experiments, Huygens concludes with his new claim (the existence of a 'matter . . . more subtle than air') and a recommendation for future work to extend his claim:

> Here is another confirmation of our hypothesis of a matter capable of exerting pressure but more subtle than air. Those who would take the

> trouble to discover up to what point the force of this pressure mounts can do no better than to pursue the experiment with the tubes full of mercury, even longer than those Mr. Boyle used. They will find perhaps that this force is powerful enough to cause the union of the parts of glass and of other sorts of bodies that hold together better than if they were joined only by contiguity and rest, as Mr. Descartes would have it. (1672–JS006)

Huygens and Henshaw differ in their goals: only Huygens is interested in explaining the phenomena that experiment reveals. It is significant that the explicit view of the far better-known Robert Boyle is coincident with Henshaw's implicit one: Boyle insisted that his 'business' was 'not ... to assign the adequate cause of the spring of the air, but only to manifest, that the air hath a spring, and to relate some of its effects'.[32] Such a view contrasts with that of Huygens, who designs a series of experiments whose purpose is to test a new hypothesis derived from a re-analysis of Boyle's experimental design.

Because Henshaw makes no claim other than that of fact, he needs no argument apart from the array of relevant data. He describes nature; he makes no attempt to understand its workings. Huygens, who makes a claim about those workings, needs a more robust argument. In satisfying this need, Huygens anticipates the form of the modern scientific article. This form is also an argument: it is meant to recapitulate, not the experimenter's story, but that of the experiment, a narrative that is also a logical progression. This progression justifies a conclusion that contains referents specific to nature, in Huygens' case, not to his elaborate tangle of glassware, but to 'matter capable of exerting pressure but more subtle than air'. The way in which he structures this argument is clearly consistent with Holmes' assertion that 'the "conventional form" imposed on the modern journal article is ... but the outcome of the long evolution of a form that emerged during the late seventeenth and early eighteenth centuries',[33] the main impetus coming from France under the auspices of the Académie Royale.

Our results in Table 1 (bottom portion) suggest that Huygens' concern for explaining his gathered facts is more characteristic of the French than the English scientific literature: 29 French articles offer explanations, while this is true of only 17 English articles. None the less, both the French and English place a healthy emphasis on the search for mechanical causes: of our 50 French articles, 19 offer mechanical explanation; of 50 English articles, 14 offer the like.

Both French and English explanations are, typically, plausible reconstructions of mechanical processes. On occasion, such mechanical explanations involve entities not visible to the explaining scientist: in Huygens' view, for example, the action of ordinary air is insufficient to explain the behaviour of devices like the barometer in the void created by an air-pump. To remedy this deficiency, Huygens hypothesizes 'subtle air'. Surprising as this may seem, in no English case in our sample of 50 articles does a mechanical explanation depend on speculations like that of Huygens concerning the basic constitution of the physical universe.

A more Galilean approach to explanation also seems to be reflected in our French sample: 16 articles have a mathematical purpose, as compared to only 5 English articles. This is consistent with Dear's assertion that 'mathematical contributions . . . fitted only uneasily into the Royal Society's [early] work'.[34] A more mathematical approach by the French may likewise account for the differences in quantitative expressions and equations found in our random sample of 200 short passages. Our average counts per 100 words for this feature were 2.48 for the French versus 1.09 for the English.[35] This contrast must not be generalized too far, however: Newton, Wallis and Halley were as Galilean as Huygens or any French researcher.

This difference in emphasis on mathematics and the quantitative is best illustrated with examples. The first, culled from an early issue of the *Philosophical Transactions*, reveals the more personal, less mathematical bent of the English sample (quantitative expressions in bold):

> I took out **45 *ounces*** and better, of blood, out of the *Jugular Vein* of a Sheep, of a lesser size than the former; by which time, the Spectators, as well as my self, found her exceeding faint, and some thought her pass'd recovery, without a supply of blood. Then I convey'd blood from the *Jugular Vein* of a Calf into that of the Sheep for the space of *7* ***minutes***, when we did believe, by the continuance of a good stream from the Calf, that the Sheep had already received more blood, than she had lost. Whereupon we set her free, and she had no sooner got her liberty, but seeing a Dog near her (which was a Spaniel, that had formerly suffered the transmission of Sheeps-blood into him) she butted with great violence at him **three or four times**, not appearing at all concern'd at what she had endured in the Experiment. (1667–PT003)

In this selection on the then-popular topic of experiments with blood transfusion, the author relates a series of events in the first person singular and plural. The three quantitative expressions act more as stage scenery than part of a coherent mathematical or mechanical explanation. Unlike 20th-century scientific prose, narrative particularity still seems to have more probative value than any measurements. The vivid scene in this passage, including the mention of 'Spectators' and the seemingly irrelevant yet amusing aside delivered in the parenthetical remark, attests to that event having happened in just that way. The text thus conveys the impression of the author as eyewitness to 'an actual, discrete event', and an active participant in that event.[36]

The original of our next example is in French, and from the end of our chosen period. It concerns the making of water-clocks, and exhibits an orientation that is definitely quantitative and mathematical, as well as impersonal:

> For there to be these **144 equal parts**, it is necessary to have **23** for the **first hour** of outflow, **21** for the **second**, **19** for the **third**, **17** for the **fourth**, and, finally, **1** for the **twelfth**, always following the natural sequence of odd numbers.

EXAMPLE II

XI.* The acceleration of the water at its exit through the hole *O* remains the same as in the last example (*art.* 8), that is to say, as the roots of the heights of the surface of the water above the hole, so that the curve *OVX* that expresses them by these ordinates is still a parabola whose locus is $v = \sqrt{px}$; if one now wants the generated curve *FEO* of the given vessel, assume any conic section whose vertex is within the circumference of *O*. (1699–MAS023)[37]

This passage has no proper names or first-person pronouns or any language referring to things extraneous to the science being reported. There is no sense of a particular place or an observer's presence, as in the first quoted passage, and the instances of quantitative expression all work in service of the author's mathematical explanation. The French author is clearly addressing colleagues, fellow labourers in the manufacture of new scientific knowledge – not the universal audience of 'Artizans, Countrymen, and Merchants' imagined by Thomas Sprat in his famous pronouncement about the preferred style by Royal Society members.[38] Still, the high standard deviation for quantitative expressions and equations in the French sample (±7.24 *versus* ±2.73 for the English) suggests that such mathematical text as the quoted French passage occurs in a relatively small percentage of samples. Overall, in the 17th century, the data within scientific articles are relatively meagre and their descriptive complexity not very far advanced, even in so mature a science as astronomy.

Depicting Argument

Visual representations also contribute to the argumentative practices at work in our 17th-century scientific texts. Because during this period the technology for reproducing figures (woodcuts, copper engravings and etchings) was still in its infancy and expensive,[39] it is not surprising to find that, of our 100 whole articles (50 French, 50 English), only 40 possess any visual representations at all. Of these 40, the average space taken up by the visuals in each article is fairly modest: 10% in the French case, 8.3% in the English.[40] These visuals vary in type – tables of results, three-dimensional drawings of equipment and of objects being investigated, and geometric representations of the operation of natural laws.[41] More important, they vary in function. Function is where their real significance lies: they provide support for the facts and the mechanical and mathematical explanations that are the central topics of argument in 17th-century science (see Table 2). The following are two examples from our French sample of the ways in which 17th-century scientists employed visuals to establish facts and offer explanations for facts.

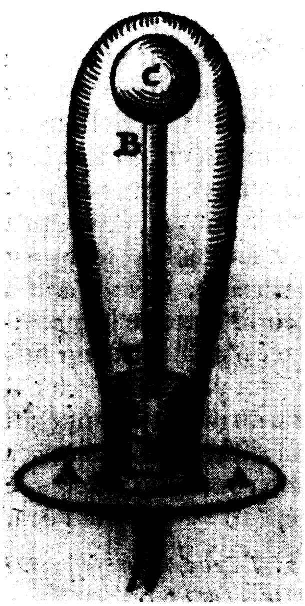
Huygens' illustration (Figure 1), taken from the article discussed previously, is a typical visual representation of an experimental apparatus designed to establish facts of nature through laboratory manipulations. Snugly embedded in the text, the stick-figure-like drawing makes use of dotted and solid lines, shading and labelling, and keeps extraneous details and embellishments to a minimum, so as better to represent the various

TABLE 2
Functions of Graphics in Sample of 100 Whole Articles (percentage of total graphics given in parentheses)

	French Articles	English Articles
Supports Observation	8 (31)	6 (43)
Supports Experimental Result	2 (8)	1 (7)
Supports Mechanical Explanation	3 (11)	1 (7)
Supports Mathematical Relation	8 (31)	3 (21)
Supports Mathematical Explanation	2 (8)	2 (14)
Supports Equipment Building	3 (11)	1 (7)
TOTAL GRAPHICS	26	14

experimental components within components (1672–JS006). This is not a deeply realistic rendering of an experimental apparatus, as in Boyle's exceptional engraving of his air-pump printed in *New Experiments Physico-mechanicall, Touching the Spring of the Air, and Its Effects (Made, for the Most Part, in a New Pneumatical Engine)*,[42] but a simplified abstraction designed better to reveal internal workings of the apparatus.

FIGURE 1
Schematic of Apparatus Used in Air-Pump Experiments



Source: from Christiaan Huygens, 'Extrait d'une lettre de M. Huygens de l'Académie Royale des Sciences à l'auteur de ce Journal, touchant les phénomenes de l'eau purgée d'air' [Extract from a letter . . . concerning the surprising behaviour of water from which all air has been removed], *Journal des Sçavans* (1672), 112–23, on 113.

Typical also is Huygens' careful explanation of this device in the running text of his article (in lieu of a figure caption), an investigation of the anomalous height of water in a tube under a vacuum created by an air-pump:

> It is necessary to imagine that the glass denoted *C C* is completely full of water, & that its open extremity dips in the water of glass *D*. Over the top of both is placed the vessel *B*, on whose open mouth is applied a certain soft cement, spread on the plate *A A*, which is pierced by a little hole in the middle, by which the air leaves when one works the pump. When I used fresh water, all of vessel *C* emptied until it was at the level with that of glass *D*. (1672–JS006)

Huygens is interested in describing the experiment so carefully that through his own words, or through subsequent replication, the fact of this anomalous liquid suspension can be established. The drawing itself gives us no clue, however, as to the mechanical cause for this fact.

Méry's illustration (Figure 2) of two foetuses enclosed in the same membrane is an example of a realistic drawing of an object of study designed to illustrate mechanical cause (1693–MAS013). The visual is clearly at the service of science: each of the technical features – the amnion, the chorion, the placenta and, especially, the knotting of the two umbilical cords – is made visually prominent by means of some combination of

FIGURE 2
Drawing of Two Strangled Foetuses

Source: from Jean Méry, 'Observation de deux Foetus enfermés dans une même enveloppe' [Observation of two foetuses enclosed in the same chorion], *Mémoires de l'Académie Royale des Sciences* 10 (1693), 201, illustration on following page.

contrast, position and labelling. Moreover, the explanation of the phenomenon – the mechanical cause of the strangulation alluded to in the article – is made visually the most prominent item, placed at the very centre of the picture, and marked by the letter 'N'. The grotesque yet accurate rendering of the foetuses flanking the knotted cord dramatizes the tragic consequences of this medical phenomenon (the wasting and ultimate death of the foetuses resulting from insufficient oxygen and nourishment through the cord), the human toll of which is outside the bounds of normal scientific discourse. This toll includes the demise of the nearly invisible mother, who is visually represented by her scientifically relevant anatomical feature alone.

While our sample of visuals for the 17th century is relatively small, we did find a few interesting differences between the French and English (Table 2). Whereas 26 (52%) of the French articles in the sample have tables or graphics, this is true of only 14 (28%) of the English articles, very possibly the result of the meagre financial backing of *Philosophical Transactions* by the Royal Society. More important, in the French and English cases, the distribution of the functions of the graphics differs somewhat. English visuals are more likely to support observational or experimental facts (50%, compared with 38% for the French articles with visuals), while French visuals are more likely to support a mechanical or mathematical explanation, or a mathematical relation (50%, compared with 43% for the English articles with visuals). Thus we find in the French case a greater use of visuals, particularly of a mathematical and explanatory nature, a use eventually to become a crucial element in scientific communication.

The Scope of Argument

We want to make a final point concerning, not argumentative practices *per se*, but their scope: English scientists exhibit a far greater breadth of subject matter than their Continental colleagues (Table 3). In the English case, in fact, we have one category of article for which there are no French

TABLE 3
Distribution according to Discipline for Articles containing 200 Selected Passages

	French	English
Animal Biology	16	16
Astronomy	21	12
Chemistry	11	5
Earth Sciences	5	6
Mathematics	10	7
Medicine	0	12
Physics	21	16
Plant Biology	13	7
Technology	3	2
Miscellaneous	0	17

instances: 'miscellaneous'.[43] The focus of the diverse articles in this category is generally on areas of human inquiry new to scientific investigation: interests are represented that would later become cartography, metallurgy, cultural anthropology and actuarial science. As a consequence of this broader English interest, the argumentative standards of 17th-century science are applied to a broader range of subjects. Science becomes more a way of looking at the world in general than a way of investigating the natural world, narrowly conceived. Halley's 'An Estimate of the Degrees of the Mortality of Mankind, drawn from curious Tables of the Births and Funerals at the City of Breslaw; with an Attempt to ascertain the Price of Annuities upon Lives', is a good example of this extension and its communicative implications:

> For these Reasons the People of this City seem most proper for a *Standard*; and the rather, for that the *Births* do, a small matter, exceed the *Funerals*. The only thing wanting is the Number of the whole People, which in some measure I have endeavoured to supply by comparison of the *Mortality* of the People of all Ages, which I shall from the said Bills trace out with all the accuracy possible.
>
> It appears that in the Five Years mentioned, viz. from 87 to 91 inclusive, there were *born* 6193 Persons, and *buried* 5869; that is, born per *Annum* 1238, and *buried* 1174; whence an *Encrease* of the People may be argued of 64 per *Annum*, or of about a 20th part, which may perhaps be ballanced by the Levies for the *Emperor's* Service in his Wars. (1693–PT041)

In this passage of actuarial findings, both Halley's style and his style of argument are indistinguishable from their counterparts in physics, biology and chemistry. In contrast, the professional status of French science is manifest in its sharper focus on subjects that are traditionally scientific. A group of scientists who clearly see themselves as astronomers, botanists, chemists, physicists or mathematicians carry out organized programmes of research.[44] Medicine is not among their chief concerns,[45] nor are they driven by a general desire to create new disciplinary interests by focusing their attention on objects and events hitherto excluded from scientific scrutiny.

Social Implications

In discussing the interesting differences between English and French scientific literature we have necessarily slighted the many similarities. Most articles in our sample could have been published, with some minor revisions and translation, in the other nation's journal literature; indeed, *Philosophical Transactions* did occasionally publish English and Latin versions of articles by European authors, including such prominent ones as Leeuwenhoek, Huygens, Hevelius, Leibniz, Varignon and Cassini. Overall, we see the writers of 17th-century scientific prose, whatever their nationality, as addressing an international community of readers engaged in a mutual quest for empirical knowledge of the natural world. Yet our rhetorically-informed analysis has revealed several different trends in argumentative practice that would appear to be national in character.

We have found that while 17th-century natural philosophers shared a common interest in fact-gathering and in explanation, the balance between these two enterprises differed from one shore of the Channel to the other. From words still vivid on the page, we can envision the English gentleman Thomas Henshaw, just after dawn on a chilly May morning, supervising his servants as they gather quantities of dew for his experiments. We cannot picture the mathematical Dutchman Christiaan Huygens similarly engaged. There is thus a special sense in which Henshaw participates in the great unrealized dream of English science, the dream in Bacon's *New Atlantis*, of a museum containing a specimen of every scientific fact. Although the flagship enterprise of Continental science – the Académie Royale – was not uninterested in Bacon's dream, as its early work on animals and plants attests,[46] its focus on explanation was greater than that of the Royal Society. Furthermore, our French sample placed a heightened emphasis on quantification, visual argument, and use of observations and experimental results as stepping stones to theory.

The relationship between 'literary inscriptions' and their sociohistorical context is never a simple one, and the reason behind the differences we have noted present a puzzle we cannot definitively solve. Nevertheless, we think that any explanation must involve the openness of the Royal Society *versus* the exclusivity that was a consequence of the professionalization of the Académie Royale.[47] Only members of the Académie Royale could publish in its *Mémoires*, a practice that skewed its contents in the direction of a small authorial community of academicians. *Journal des Sçavans* relied heavily upon this same limited community for its contents.[48] While the professionalization of science on a large scale would not take place until the middle of the 19th century, in Germany, when most working scientists were 'either university teachers or students, and they worked more and more in groups consisting of a master and several disciples',[49] the incipient professionalization of French science is already evident in the early years of the Académie Royale and the two journals in which its members published their research findings.[50]

In contrast, even though closely tied to the Royal Society, the early *Philosophical Transactions* published articles by men,[51] both inside and outside that community, including scientific correspondence sent to the editor from seafarers, physicians, world travellers, European savants, and the like. Thanks to its founder and first editor, Henry Oldenburg, *Philosophical Transactions* delivered on the promise of its title page: 'Giving some accompt of the present undertakings, studies, and labours of *the ingenious in many considerable parts of the world*' (italics added). And the articles therein favoured the reporting of observationally derived facts *sans* theoretical explanations.

It is also worth bearing in mind that, in the French case, the relationship between professionalization and scientific explanation is not straightforward. It is not that we have, as a direct consequence of this narrowing, a

Cartesianism that insists science deliver a material cause, or the Galilean view that the book of nature is necessarily 'written in the language of mathematics'. Rather, this narrowing – coupled by the talents of such as Huygens or Varignon – opens one set of opportunities for French science while closing off another. While the English are open to 'natural science as a model for valid thinking about political, economic, and technological matters',[52] the French pursue a narrower goal with singular intensity. Between this French pursuit of narrower goals and instrumental precision, the path is direct, a concern for such precision being the only means of linking theory firmly to observations and experimental results. During the 18th century, we suspect, these interesting differences will become less pronounced as French science diversifies with the proliferation of scientific journals and societies,[53] while the English scientific article comes more closely to resemble the French example under the powerful sway of Isaac Newton and his disciples.[54]

Appendix: Questionnaire for Argumentative Practices

Questions asked of randomly selected whole articles, 50 English and 50 French, except for 'hedging' and 'quantitative' statements, where questions asked of randomly selected ten-line passages, 100 English and 100 French.

Verbal Argument

1. Is the article's content a) experimental? b) theoretical? c) methodological? d) observational? e) observational/theoretical? f) experimental/theoretical? g) experimental/methodological? h) medical/surgical? i) mathematical?
2. Is the article's main claim an a) observation? b) experimental results? c) mechanical explanation? d) mathematical rule? e) mathematical explanation? f) making or improving equipment?
3. Is there any mention of witnesses to an observation or experiment?
4. How many hedging expressions are there per 100 words? Examples include: 'il y a des conjonctions qui **paroissent** précises' (1692–MAS080); 'mon sentiment, **s'il est vrai**, perfectionne ce qu'il y a **de général** dans son Systême' (1699–MAS051); 'that those veins do any where grow less and smaller, though **probably it may be so**' (1672–PT063).
5. How many quantifying expressions and equations are there per 100 words? Examples include: 'A **2 heures 48'**, la Lune étoit éclipsée de **9 doigts 58"** (1692–MAS041); 'Soient enfin **AE = x**, **EB = y**, & **EF = z**' (1699–MAS067); 'It appears that in the **Five Years** mentioned, viz. from **87 to 91** inclusive, there were *born* **6193 Persons**, and *buried* **5869**' (1693–PT041).

Visual Argument

1. How many graphics in articles (tables and figures)?
2. What is percent of space of graphics (tables and figures)?
3. If there is a graphic, is it of a) equipment? b) experimental arrangements? c) natural object? d) is it a list? e) a table? f) a mathematical relation?
4. If there is a graphic, does it support a) an observation? b) an experimental result? c) a mechanical explanation? d) a mathematical relation? e) a mathematical explanation? f) improving equipment?

Notes

This research was supported at various times by grants from the University of Minnesota and the Society for Technical Communication, and was accomplished in part while the first author was in London as a British Association Visiting Professor as well as a Fellow at the Center for the Philosophy of Science, University of Pittsburgh; the Institute for Advanced Studies, Hebrew University; and the Internationales Forschungszentrum Kulturwissenschaften. The contribution of the second author was performed independently of his institutional affiliation. We thank the journal referees for their astute and constructive comments on the original manuscript. Photographs courtesy of University of Minnesota libraries.

1. Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, NJ: Princeton University Press, 2nd edn, 1986), 49.
2. Two other early sociological studies involving analysis of scientific texts are G. Nigel Gilbert and Michael Mulkay, *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse* (Cambridge: Cambridge University Press, 1984), and Karin D. Knorr-Cetina, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Oxford: Pergamon Press, 1981). Among other insights, these studies found that the modern scientific article represents a rational reconstruction of scientific work, one that distorts the true nature of that work and suppresses some of its underlying motivations.
3. Our review of the last 15 years' worth of *Social Studies of Science*, for example, turned up the following studies with a strong rhetorical slant: Charles Bazerman, 'Modern Evolution of the Experimental Report in Physics: Spectroscopic Articles in *Physical Review*, 1893–1980', *Social Studies of Science*, Vol. 14, No. 2 (May 1984), 163–96; Greg Myers, 'Texts as Knowledge Claims: The Social Construction of Two Biology Articles', *ibid.*, Vol. 15, No. 4 (November 1985), 593–630; Myers, 'Politeness and Certainty: The Language of Collaboration in an AI Project', *ibid.*, Vol. 21, No. 1 (February 1991), 37–73; Myers, 'From Discovery to Invention: The Writing and Rewriting of Two Patents', *ibid.*, Vol. 25, No. 1 (February 1995), 57–105; Bryce Allen, Jian Qin and F.W. Lancaster, 'Persuasive Communities: A Longitudinal Analysis of References in the *Philosophical Transactions* of the Royal Society, 1665–1990', *ibid.*, Vol. 24, No. 2 (May 1994), 279–310; Benoît Godin, 'The Rhetoric of a Health Technology: The Microprocessor Patient Card', *ibid.*, Vol. 27, No. 6 (December 1997), 865–902; Harro van Lente and Arie Rip, 'The Rise of Membrane Technology: From Rhetorics to Social Reality', *ibid.*, Vol. 28, No. 2 (April 1998), 221–54. In the first of these papers, Bazerman investigated the changing character of communication in 20th-century physics. In three separate papers, Myers analyzed the negotiation of the breadth of biological claims during peer review, the function of politeness strategies in scientific decision-making, and the status of knowledge claims in patents as distinct from scientific papers. Allen, Qin and Lancester examined citation patterns in the *Philosophical Transactions* as a window on to the persuasive practices of scientific communities over time. Moving in a different direction, van Lente and Rip integrated rhetorical analysis into their examination of the creation of a new social reality in 'membrane technology', and Godin proceeded similarly in tracing the social history of the Canadian microprocessor patient card. Although the evidence from the dates of these articles is no more than suggestive, and hardly constitutes a trend, it does suggest a growing interest in the rhetoric of science and technology: 1984, 1985, 1991, 1994, 1995, 1997, 1998.
4. There are many excellent historical works on the early journals and scientific societies, including Sherman B. Barnes, 'The Scientific Journal, 1665–1730', *The Scientific Monthly*, Vol. 38 (1934), 257–60; Raymond Birn, 'Le journal des savants sous l'Ancien Régime', *Journal des Savants* (Janvier-Mars 1964), 15–35; Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803* (Berkeley: University of California Press, 1971); Marie Boas Hall, 'The Royal Society's Role in the Diffusion of Information in the Seventeenth Century', *Notes and Records of the Royal Society*, Vol. 29

(1975), 173–92; David A. Kronick, *A History of Scientific & Technical Periodicals: The Origin and Development of the Scientific and Technical Press 1665–1790* (Metuchen, NJ: Scarecrow Press, 1976); Hub Laeven, *The* Acta Eruditorum *under the Editorship of Otto Mencke (1644–1707): The History of an International Learned Journal between 1662–1707* (Amsterdam: Holland University Press, 1990); Roger Philip McCutcheon, 'The *Journal des Sçavans* and the *Philosophical Transactions* of the Royal Society', *Studies in Philology*, Vol. 21 (1924), 626–28; James E. McClellan, III, *Science Reorganized: Scientific Societies in the Eighteenth Century* (New York: Columbia University Press, 1985); Douglas McKie, 'The Scientific Periodical from 1665 to 1798', *Philosophical Magazine*, Commemorative Issue (1948), 122–32; Martha Ornstein, *The Role of Scientific Societies in the Seventeenth Century* (Chicago, IL: The University of Chicago Press, 2nd edn, 1928); Dorothy Stimson, *Scientists and Amateurs: A History of the Royal Society* (New York: Greenwood Press, 1968); Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences* (Berkeley: University of California Press, 1990).

5. From work cited in note 4, see Hahn, 1–34; Hall; McClellan, 41–66; Stroup, 3–61.
6. McClellan (op. cit. note 4, 30) notes that in the 18th century the Royal Society did receive governmental funding for 'several [large] expeditions and projects that had an immediate bearing on the government's interests in navigation, trade, and colonial expansion'.
7. Henry Oldenburg, *Correspondence*, ed. and trans. A. Rupert Hall and Marie Boas Hall (Madison: University of Wisconsin Press, 1965–86).
8. Stroup, op. cit. note 4, 34.
9. Joseph Ben-David, *The Scientist's Role in Society: A Comparative Study* (Englewood Cliffs, NJ: Prentice Hall, 1971), 82.
10. Steven Shapin, 'Pump and Circumstance: Robert Boyle's Literary Technology', *Social Studies of Science*, Vol. 14, No. 4 (November 1984), 481–520; Jan V. Golinski, 'Robert Boyle: Scepticism and Authority in Seventeenth-Century Chemical Discourse', in Andrew E. Benjamin, Geoffrey N. Cantor and John R.R. Christie (eds), *The Figural and the Literal: Problems of Language in the History of Science and Philosophy, 1630–1800* (Manchester: Manchester University Press, 1987), 58–82.
11. Alan G. Gross, *The Rhetoric of Science* (Cambridge, MA: Harvard University Press, 2nd edn, 1996), 119–28.
12. Charles Bazerman, 'Forums of Validation and Forms of Knowledge: The Magical Rhetoric of Otto von Guericke's Sulfur Globe', *Configurations*, Vol. 1 (1993), 201–27.
13. In addition to the work of Allen, Qin and Lancaster, discussed in note 3, see: Charles Bazerman, *Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science* (Madison: University of Wisconsin Press, 1988), 59–79; Ellen Valle, 'A Scientific Community and Its Texts: A Historical Discourse Study', in Britt-Louise Gunnarsson, Per Linell and Bengt Norberg (eds), *The Construction of Professional Discourse* (London: Longman, 1997), 76–97; Dwight Atkinson, *Scientific Discourse in Sociohistorical Context: The* Philosophical Transactions *of the Royal Society of London, 1675–1975* (Mahwah, NJ: Lawrence Erlbaum Associates, 1999). Our study differs from these earlier ones in several respects, most importantly in the comparison with the French journals, but also in our method for selecting and analyzing texts.
14. For a historically-based analysis of select rhetorical features of English prose in the 17th century, see Peter Dear, '*Totius in Verba*: Rhetoric and Authority in the Early Royal Society', *Isis*, Vol. 76, No. 282 (June 1985), 145–61. For a historical treatment of early French scientific articles, see Frederic L. Holmes, 'Argument and Narrative in Scientific Writing', in Dear (ed.), *The Literary Structure of Scientific Argument* (Philadelphia: University of Pennsylvania Press, 1989), 164–81.
15. In *De Elocutione*, Demetrius noted: 'If anybody should write of logical subtleties or questions of natural history in a letter, he writes indeed, but not a letter'; quoted in Abraham J. Malherbe, *Ancient Epistolary Theorists* (Atlanta, GA: Scholars Press, 1988), 19.

16. Chaïm Perelman and Lucie Olbrechts-Tyteca, trans. John Wilkinson and Purcell Weaver, *The New Rhetoric: A Treatise on Argumentation* (Notre Dame, IN: University of Notre Dame Press, 1969).
17. See Shapin, op. cit. note 10; Gross, op. cit. note 11; Bazerman, op. cit. note 13; Dear (1985), op. cit. note 14; Holmes, op cit. note 14; Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago, IL: The University of Chicago Press, 1995); Lorraine Daston and Katharine Park, 'Strange Facts', in their *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1998), 215–54.
18. In the Appendix at the end of this paper, we present the set of questions we derived from the topics of argument.
19. Ken Hyland, *Hedging in Scientific Research Articles* (Amsterdam: John Benjamins, 1998); Greg Myers, 'The Pragmatics of Politeness in Scientific Articles', *Applied Linguistics*, Vol. 10 (1989), 1–35, esp. 12–20.
20. Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton University Press, 1995), 73–86.
21. Robert Mortimer Gascoigne, *A Historical Catalogue of Scientific Periodicals, 1665–1900, with a Survey of their Development* (New York: Garland Publishing, 1985). In this book, Gascoigne ranks the available 17th- and 18th-century journals on the basis of the number of prominent 'scientists' who published in a given journal over a select period. The other two 17th-century journals listed by Gascoigne, *Miscellanea Curiosa* and *Acta Eruditorum*, originated in German-speaking lands and adopted Latin to reach the widest possible audience.
22. These references indicate year of publication, journal abbreviation (PT = *Philosophical Transactions*, JS = *Journal des Sçavans*, and MAS = *Mémoires de l'Académie Royale des Sciences*), and our working code number.
23. Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press, 1985), 24.
24. This expectation did not, of course, eliminate the occasional appearance of unfounded or ludicrous assertions. In his *Review of the Works of the Royal Society* (London, 1751), John Hill mercilessly criticized *Philosophical Transactions* for publishing 'trivial and downright foolish articles' over the previous century. As evidence, he cited articles on a merman discovered in Virginia, and a miraculous plant that heals fresh wounds ('but to touch it, is to be healed'), as well as 'incontestible proofs of a strange and surprising Fact, namely, that Fish will live in Water'. Not long after Hill's scathing attack, in 1752, the Society established a committee to review articles for publication on the basis of 'the importance and singularity of the subjects, or the advantageous manner of treating them': see Stimson, op. cit. note 4, 141. Worth noting, however, is that our sample of 100 randomly selected English and French articles did not have any obvious examples of ill-advised articles like those criticized by Hill.
25. Myers (1989), op. cit. note 19, 12–20.
26. The much lower French average for hedging may reflect inherent differences in the two languages, as well as less concern with the open display of gentlemanly politeness than among the English.
27. For comparison, we found that an analogous sample drawn from the 20th century yielded hedge counts of 1.82 and 1.29 instances per 100 words for English and French scientific articles, respectively.
28. This controversy, the first major open dispute in the scientific journal literature, has been much analyzed by both historians and rhetoricians of science. See, for example, Gross, op. cit. note 11, 111–128; Bazerman, op. cit. note 13, 80–127; and Richard S. Westfall, *The Life of Isaac Newton* (Cambridge: Cambridge University Press, 1993), 85–109.
29. Shapin & Schaffer, op. cit. note 23, 225–82, quote at 281.
30. Alan Shapiro, 'The Gradual Acceptance of Newton's Theory of Light and Color, 1672–1727', *Perspectives on Science*, Vol. 4 (1996), 59–140, at 61.

31. John Swales, *Genre Analysis: English in Academic and Research Settings* (Cambridge: Cambridge University Press, 1990), 137–66.
32. Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago, IL: The University of Chicago Press), 335. This is not to say, of course, that Boyle did not have in mind a causal explanation for the 'spring of the air', only that he hesitated to spell it out for public consumption in his written communications.
33. Holmes, op. cit. note 14, 165.
34. Dear, op. cit. note 14, 159.
35. For comparison, we found that a similar analysis of passages from the 20th century yielded 3.28 and 2.82 instances per 100 words for English and French scientific articles, respectively.
36. Dear, op. cit. note 14, 152. Note that our sample also contains many passages focused on the natural world, with the observer more in the background, as in the earlier quoted passage of Lister (1672–PT063). Furthermore, in our sample of 100 English passages, we found little evidence that 'Fellows of the Royal Society *filled their descriptions* with contingent details of time and place in order to convey the impression that these were actual events, of which the authors were faithful reporters' (Holmes, op. cit. note 14, 165, italics added). In the midst of maritime observations, the Englishman Stubbs does report that his ship sailed off course 'to avoid the *Spanish* Fleet' (1668–PT010), but only a few such apparently extraneous statements appear in our sample. Our own general impression is that when there are details of time and place, as is often the case in reports of astronomical observations, they almost always provide essential information to the technical matter at hand.
37. The original French passage reads as follows:

> De sorte que de ces 144 parties égales il en faut prendre 23, pour le premiere heure de l'écoulement; 21, pour la seconde; 19, pour la troisiéme; 17, pour la quatriéme; & enfin 1, pour la douziéme, toûjours suivant la suite naturelle des nombres impairs.
>
> EXEMPLE II
>
> XI.* La vîtesse de l'eau à la sortie par le trou *O*, demeurant la même que dans l'exemple précedent (*art.* 8), c'est à dire, comme les racines des hauteurs de la surface de l'eau par dessus ce trou, ensorte que la courbe *OVX* qui les exprime par ses ordonnées, soit encore une parabola dont le lieu soit $v = \sqrt{px}$; si l'on veut présentement que la courbe géneratrice *FEO* du vase donné, soit une section conique quelconque dont le sommet soit en *O*.

38. Thomas Sprat, *History of the Royal Society of London, For the Improving of Natural Knowledge* (London: J. Martyn & J. Allestry, 1667), 113.
39. The expense did not impede the production of books that were magnificently illustrated and designed, such as Robert Hooke's *Micrographia: or, Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses* (London, 1665) and the Accademia del Cimento's *Saggi di Naturali Esperienzi* (Florence, 1667). For a vivid portrait of the costs and perils associated with 17th-century publishing in natural philosophy, see Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago, IL: The University of Chicago Press, 1998), 444–542.
40. Printing technology at this time allowed for text to accompany tables, but engravings are inserted separately (often at the end of the journal issue), and the relative space taken up by illustrations depends on how many fit on to a single plate, not on their argumentative importance to the articles they illustrate.
41. For a discussion of the later use of graphs, their rôle in argumentation, and the distribution of their use across 20th-century science, see Laurence D. Smith, Lisa A.

Best, D. Alan Stubbs, John Johnston and Andrea Bastiani Archibald, 'Scientific Graphs and the Hierarchy of the Sciences: A Latourian Survey of Inscription Practices', *Social Studies of Science*, Vol. 30, No. 1 (February 2000), 73–94, esp. 74–76, 84–87.

42. See Shapin & Schaffer, note 23, 27.
43. All of our categories of science are anachronistic, with the possible exceptions of astronomy, chemistry, mathematics and medicine. In applying these categories to the 17th century, we have attempted merely to identify what these men were doing, with no pretence that they would have identified their tasks exactly as such. Some of our other terminology must be so viewed: for example, 'scientist', and even 'experiment'.
44. Hahn, op. cit. note 4, 16.
45. This finding is a little deceptive in that some of the Académie Royale research in plant and animal biology had an underlying medical motivation. As Stroup points out (op. cit. note 4, 172–73), nearly 30% of the 17th-century Académie members had been trained as physicians or apothecaries, yet the Académie 'established its scientific program to be independent of medical research'. Also, at this time in France, medicine was already a well-developed discipline with various career tracks available, including academic ones.
46. Denis Dodart, 'Mémoire pour Servir à l'Histoire des Plantes', in *Mémoires de l'Académie Royale des Sciences depuis 1666 jusqu'à 1699*, Tome IV (1731), 121–333; Claude Perrault, *Mémoires pour Servir à l'Histoire Naturelle des Animaux* (Paris, 1671).
47. See also Holmes, op. cit. note 14, 177–78.
48. While translations of articles by Robert Boyle and other English authors did appear in *Journal des Sçavans*, it is worth noting that our complete random sample of French whole articles and short passages contains only two authors not members of the Académie Royale (Francine and Bernoulli), neither of them English.
49. Ben-David, op. cit. note 9, 108.
50. This early professionalization, as well as its financial underpinnings, has been masterfully documented by historian Alice Stroup (op. cit. note 4).
51. Not surprising but sad to say, this openness did not extend to women authors. Atkinson (op. cit. note 13, 102) reports that the first article with a woman listed as author did not appear in *Philosophical Transactions* until 1760: 'Effects of a Thunderstorm at Rickmansworth, Herts', by Ann Whitfield. The astronomer Caroline Herschel reported her sightings of comets in several short *Philosophical Transactions* articles published in the 1790s.
52. Ben-David, op. cit. note 9, 108.
53. McClellan, op. cit. note 4, 67–68, 89–99.
54. For good discussions of the argumentative practices in the 18th-century *Philosophical Transactions*, see this work cited in note 13: Bazerman, 59–79; Valle; and Atkinson, 75–109.

Alan G. Gross is Professor of Rhetoric at the University of Minnesota, and author of *The Rhetoric of Science* (Harvard University Press, 2nd edn, 1996). At present, he is at work on a book tracing the development of the scientific article from its modest beginnings in 17th-century England and France to the international phenomenon it is today. He is joined in that endeavour by **Joseph E. Harmon**, a senior technical editor at Argonne National Laboratory, and **Michael S. Reidy**, who recently completed his PhD in the history of science at the University of Minnesota, and is now at the University of Oklahoma. Harmon and Gross also recently served as guest curators for an exhibition of scientific texts at the Regenstein Library, University of Chicago.

Addresses: (AGG) Department of Rhetoric, University of Minnesota, St Paul, Minnesota 55108, USA; fax: +1 651 638 9021; email: grossalang@aol.com

(JEH) Chemical Technology Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439, USA; fax: +1 630 972 4404; email: harmon@cmt.anl.gov

(MSR) History of Science Department, University of Oklahoma, 601 Elm Avenue, Norman, Oklahoma 73019, USA; fax: +1 405 325 2363; email: mreidy@ou.edu