CHAPTER ONE

Introduction

Eighteenth-century Britain witnessed the development of a vibrant philosophical instrument trade in light of the popularization of Newtonian natural philosophy in the public sphere.[1] In some quarters Newton's science gained prominence on the weight of its practical utility in industry, its potential to solve numerous technical problems, and because of its vogue as a fashionable intellectual endeavor. Lecturers made lucrative careers meeting the growing demand for natural philosophy in the public market, demonstrating both intellectually stimulating and entertaining philosophic principles to paying audiences. The philosophic instrument trade grew in parallel to the lecturing market as the demand for experimental apparatus increased among the growing legions of lecturers, and among members of the public who sought to replicate what they viewed at demonstrations. These instrument-makers occupied a middle-ground between the worlds of the scientific elites and the public marketplace. By examining the way they marketed and protected their wares, one can gain insight into the nature of the eighteenth-century instrument market. This project looks specifically at how instrument-makers functioned in both the worlds of the philosophic elite and public marketplace, and by examining their commercial and patenting activity, one can reveal how important credibility and authority was to the way they did business. Furthermore, this study looks at how the apparatus of science was consumed in the public market, revealing a broad picture of eighteenth-century public science.

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[1] For an examination of the eighteenth-century emergence of the 'public sphere' see Jürgen Habermas, *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society*, (Cambridge, MA: MIT Press, 1962).

Historiography

This project is influenced by the tenets of constructivism as described by Jan Golinski, who holds that "… scientific knowledge is a human creation, made with available material and cultural resources, rather than simply the revelation of a natural order that is pre-given and independent of human action."[2] This is an answer to positivism, a relic of the enlightenment vision of science, which assumed scientific knowledge was a progressively cumulative enterprise which sought to unveil the immutable laws that governed nature. Furthermore, it had supposed this march of progress was guided by its own internal logic and was impervious to external forces.[3] The positivist perception of the nature of scientific knowledge remained prominent into the first half of the twentieth century and influenced the way that historians studied science. Specifically, the historian's methodology was restricted to identifying scientific breakthroughs as they fit into a progressive chain of discovery, and highlighting the lives of great 'heroic' scientists who revealed nature's laws. William Whewell, a nineteenth-century British historian, philosopher and scientist, aptly described the general methodology employed by positivists: "In our history," he wrote in the late 1830s "it is the *Progress* of knowledge only which we have to attend to…" because "…the existence of clear Ideas applied to distinct Facts will be discernable to the History of Science, whenever marked advance takes place" (original emphasis).[4] From Whewell's perspective the historian's attention should be focused on points of scientific advancement or the fruits of scientific enquiry. There is no interest in what caused

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[2] Jan Golinski, *Making Natural Knowledge: Constructivism and the History of Science*, (Chicago: University of Chicago Press, 1998), 6.
[3] Ibid., 3.
[4] Whewell quoted in Ibid.

scientific advancement, because it is given: ‘clear ideas’ and ‘distinct facts’ were perceived as absolutes found in nature.

By the late 1930s historians and sociologists began to look at how external influences shaped scientific enquiry. Robert K. Merton proposed that the growth in scientific activity in early-modern England was caused by external forces:

> From the middle of the seventeenth century, science and technology claimed an increasing meed (*sic*) of attention. No longer an errant movement finding faltering expression in occasional discoveries, science had become accredited and organized. To this, the establishment of the Royal Society bears some witness. But all this was no spontaneous generation. It had its antecedents rooted deep in the culture which fathered it and assured its further growth; it was a child of a long period of cultural growth.[5]

For Merton it was Protestantism that provided the science-friendly cultural influence in early-modern England because “Puritan principles undoubtedly represent to some extent an accommodation to the current scientific and intellectual advance.”[6] Puritans shared core values that intersected with those of the natural philosopher, and hence, Merton deduced that Puritan sites were environments conducive to scientific enquiry. He maintained these external forces influenced the speed of scientific advancement, and produced environments favorable to scientific investigation. However, he also held the external influences had no bearing on the direction of science once firmly institutionalized, as, for example, in the form of an established entity like the Royal Society of London.[7] Therefore, upon institutionalization, Merton also viewed science within a positivist framework. For science to gain institutionalization and become insulated from external influences, he proposed a scientific ‘ethos’ had to be achieved.

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[5] Robert K. Merton, *Science, Technology, and Society in Seventeenth-Century England*, 2nd ed, (New York: Harper and Row, 1970), 55.
[6] Ibid., 80-81.
[7] Golinski, *Making Natural Knowledge*, 49.

This ethos consisted of four broad principles or norms: ‘universalism,’ ‘communism,’ ‘disinterestedness,’ and ‘organized skepticism’ or peer review.[8] For Merton, the ‘four norms’ had been achieved within the walls of the Royal Society once Robert Boyle had established his programme of experimental philosophy in the 1660s. Thereafter the Royal Society’s science was, in his view, governed only by the internal logic of natural law. Nonetheless, the importance of the Mertonian scheme was that it provided historians with a methodology to explore the social environments and those external forces by which scientific institutions appeared to develop. This widened the territory historians of science would explore.

The major challenge to positivism came from Thomas Kuhn’s *The Structure of Scientific Revolutions* published in 1962. Kuhn claimed the validity of scientific knowledge was dependent, not on the immutable laws of nature, but rather, on the way that scientific ‘facts’ fit into a theoretical framework, or “paradigm,” constructed by a community of scientists.[9] Essentially, he postulated that historically science had undergone periods punctuated by normalcy and revolution. ‘Normal’ science is represented by a paradigm which Kuhn describes as a “…universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners.”[10] Within this paradigm, a community of scientists is established and subscribes to a specific scientific theoretical framework that is supported by facts discovered through observation. However, a paradigm would break-down upon the discovery of new facts or “anomalies” that did not fit into the current theoretical

[8] Ibid.
[9] Ibid., 14.
[10] Kuhn quoted in Ibid.

framework.[11] Consequently scientists respond, through social consent, by developing a new paradigm that incorporates the newly discovered 'facts,' and meanwhile, discard the old paradigm. Thus, Kuhn maintained Newton's theory of light and colours replaced other optical paradigms because it could more clearly account for the length of the colour spectrum; it was subsequently replaced by a different wave theory because that incorporated anomalies concerned with diffraction and polarization.[12] Kuhn also claimed large dramatic scientific revolutions were caused by major paradigm shifts. Specifically, he refers to the transition from the Ptolemaic to Copernican view of the universe, and the acceptance of Antoine Lavoisier's pneumatic chemistry over Joseph Priestley's phlogiston theory as examples of major paradigm shifts in the history of science.[13]

For Kuhn, paradigms were not governed by the discovery of immutable law, but rather they provided theoretical frameworks, learned through socialization and education, and were used to solve specific scientific problems.[14] When new scientific evidence created a controversy it was a social process – the need for consent – that induced a new paradigm. In the late 1960s and early 1970s sociologists and historians began to use Kuhnian philosophy as a way to challenge the positivist monopoly over science studies. In 1971 M. D. King expressed the implications of Kuhn cogently in "Reason, Tradition, and the Progressiveness of Science." He stated that Kuhn:

> …questions what Merton, no less the positivists, simply take for granted: that cognitive development of science is a rational process governed by timeless rules of procedure. In fact he denies that such standards exist and

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[11] Ibid.
[12] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1964), 67.
[13] Ibid, 56, 66; also, Golinski, *Making Natural Knowledge*, 14.
[14] Golinski, *Making Natural Knowledge,* 16-17.

> maintains that the practice of science is monitored not by universal rules but by 'local' traditions of thought.[15]

According to King, it was the scientific community, practicing in a type of cultural tradition, who controlled the direction of science and not a predetermined set of natural laws. This, then, provided the sociologist and the historian with "…the opportunity of developing the kind of approach that serves more to illuminate actual historical processes of change in the patterns of thought, mode of practice, and social situation of scientists, than to meet the demands of epistemology."[16] Assuming scientific knowledge is not singularly directed by a natural law but, rather, motivated by social forces, scientific practice could be examined like any other cultural phenomenon. Kuhn had provided the foundation for a new generation of historians of science, the constructivists, who assumed that science was largely influenced by social forces.

Constructivism, developed from what was called the 'strong programme,' was popularized by Barry Barnes, David Bloor, and later Steven Shapin of the Edinburgh Science Studies Unit (ESSU) in the late 1960s and early '70s.[17] Armed with their interpretation of Kuhn these theorists promoted their constructivist methodology and outlined the strong programme's dedication to examining science as a cultural phenomenon. For example Barnes' "Paradigms – Scientific and Social" of 1969, maintained that anthropological methods could prove to be an effective tool to help understand the nature of scientific paradigm changes.[18] In 1971 ESSU went beyond simply outlining the goals of the 'strong programme' and established the journal *Science*

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[15] King quoted in John H. Zammito, *A Nice Derangement of Epistemes: Post-Positivism in the Study of Science from Quine to Latour*, (Chicago: University of Chicago Press, 2004), 130.
[16] Ibid.
[17] Zammito, 131.
[18] Ibid.

Studies, which was used as a focal point for attacking the Mertonian and positivist position on science.[19] By 1972, Richard Whitley had made a very apt assessment of what had been developing within the sociology and history of science, stating that: "Kuhn's *Structure of Scientific Revolutions* has had a considerable impact on the British Sociology of Science… [by] linking changes in cognitive structures to sociopsychological phenomena, Kuhn legitimated sociologists' revolt against Merton."[20] By the end of the 1970s and into the 1980s the constructivist 'strong programme' had been overwhelmingly endorsed by sociologists and historians of science. During this period Steven Shapin began to produce some of the most significant constructivist historical work, and convincingly replaced the Mertonian approach to the history of science.

Shapin's most notable early publications focused largely on the history of phrenology. "Phrenological knowledge and the Social Structure of Early Nineteenth-Century Edinburgh" (1975), "*Homo Phrenologicus*: Anthropological Perspectives on an Historical Problem" (1979), and "The politics of Observation: Cerebral Anatomy and Social Interests in the Edinburgh Phrenology Disputes" (1982) were exceptionally important to the constructivist school because they address the physical basis of psychology. Phrenology was, perhaps, one of the most obvious examples of socially motivated science throughout history. These works were fundamental to the establishment of constructivism within the history of science. However, it was his collaborative effort with Simon Schaffer in 1985, in *Leviathan and the Air Pump: Hobbes, Boyle and the Experimental Life*, that firmly established constructivism within the methodology of the history of science.

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[19] Ibid., 132.
[20] Ibid., 135.

Leviathan and the Air Pump ingeniously challenges the Mertonian assumption that scientific examination could become autonomous and impervious to external factors by reevaluating his scheme of the four 'norms': 'universalism,' 'disinterestedness,' organized skepticism,' and 'communism' that resulted in a scientific 'ethos.' Merton and his followers, the most important being Joseph Ben-David, maintained the Royal Society of London had achieved the four 'norms' at some point during the 1660s and thereafter science was completely insulated from external forces and followed its own internal direction.[21] However, Shapin and Schaffer maintain that the norm of 'communism' (practitioner solidarity) had never been achieved and therefore the 'ethos' that promoted pure science had never existed.[22]

Shapin and Schaffer examined the epistemological debate between Robert Boyle and Thomas Hobbes regarding the accuracy of experimental natural philosophy in the second half of the seventeenth-century. Hobbes vehemently rejected Boyle's experimental programme because it produced artificial and subjective 'facts' (both because of inconsistent laboratory apparatus and arbitrary methodology) that could not achieve the epistemological accuracy of natural philosophy.[23] The fact that Hobbes attacked Boyle demonstrates, according to Shapin and Schaffer, that the norm of 'communism' was not achieved; nonetheless, the Royal Society's scientific program flourished under these conditions. For Shapin and Schaffer, Boyle's philosophy was successful, not because it was correctly scientific, but because he presented it in a persuasive fashion. His experiments, though developed and practiced in private, were

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[21] Golinski, *Making Natural Knowledge,* 52-53.
[22] Ibid., 53, 57.
[23] Steven Shapin and Simon Schaffer, *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life*, (Princeton: Princeton University Press, 1985), 111, 146-147.

displayed in front of audiences composed of Royal Society fellows who discussed the validity of the experiment and determined if what they saw was a legitimate scientific discovery.[24] Boyle had convinced many, but not all, of the members of the Royal Society that his experimental natural philosophy was an empirical endeavor revealing natural 'facts.' Shapin and Shaffer maintain that had Hobbes possessed the same methods of persuasion as Boyle, his epistemology may have been successful within the Royal Society.

Leviathan and the Air Pump was extremely influential in promoting the constructivist perspective within the history of science. Nonetheless, its argument is not the final word. Debatably, Merton's idea of the 'scientific ethos' had been achieved because the norm of 'communism' may have been met. Boyle had won a significant number of followers (more than detractors) who believed in and expanded his experimental program. A scientific 'ethos' was potentially established because Boyle convinced a large enough group of natural philosophers to sustain and institutionalize the experimental process. Nonetheless, the success of *Leviathan and the Air Pump* relies little on its challenge to the existence of the norm of communism - this is in fact ultimately irrelevant. The strength of this work lies in the treatment of scientific knowledge production as a socially-guided phenomenon. Scientific 'matters of fact' were determined by gentlemen fellows of the Royal Society who witnessed experimental demonstrations and decided if what they saw was indeed an empirical display of nature's laws.[25] Shapin's subsequent work focuses on the nature of the authorities who determined what constituted legitimate natural knowledge – specifically, the gentleman philosopher.

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[24] Ibid., 78.
[25] Steven Shapin, "The House of Experiment in Seventeenth-Century England," *Isis* 79, no.3 (September, 1988): 382.

"The House of Experiment in Seventeenth-Century England" is one of Shapin's key explorations of scientific authority and the construction of scientific knowledge. He describes the spaces where experimental philosophy was performed, specifically within the rooms of the Royal Society, the leading institution for experimental natural philosophy. The most important message to come out of this work is that experiments were tried in 'private' by practitioners like Boyle's assistant Robert Hooke in order to develop a consistent experiment, and once perfected, would be demonstrated to an audience of gentlemen who would discourse upon the success or failure of the experiment.[26] For Boyle, to determine if the experiment produced 'matters of fact,' public discussion had to take place. In the seventeenth-century world of science, the acceptance or denial of 'matters of fact' depended not on an infallible scientific method, but rather on the perceived validity of a social body that deemed the experiments legitimate.[27] Shapin's *A Social History of Truth: Civility in Seventeenth-Century England* makes the connection between gentlemanly authority, trust, and the production of scientific knowledge. Gentlemen were viewed as the most credible judges of truth claims because the established virtuosi culture was based on principles of honour and politeness, and they were presumably isolated from concerns of money or outside interests.[28] For Shapin a "trust-dependency of social order" was the overriding social element that truth and scientific validation depended on.[29] Basically, gentlemen fellows of the Royal Society would politely discuss the merits or flaws of an experimental demonstration they had

[26] Ibid., 382.
[27] Ibid., 396.
[28] Barbara Beigun Kaplan, review of *A Social History of Truth: Civility and Science in Seventeenth-Century England*, by Steven Shapin, *The American Historical Review* 102, no.4 (October, 1997): 1157.
[29] Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, (Chicago: University of Chicago Press, 1994), 8.

viewed, and decide if what they saw was valid scientific knowledge. The most crucial part of the process, determining 'matters of fact,' was left to those who were viewed by society as the most credible – the members of the highest social stratum. The archetype of the gentlemanly natural philosopher continued to exist within the Royal Society well into the eighteenth century. But the researcher was not, of course, motivated by profit or private gain, but by the pursuit of knowledge, was deemed a trustworthy scientific authority.

Even so by the early eighteenth century, natural philosophy became a desirable commodity within British society on the strength of its alleged utility. Upon the establishment of the Royal Society in 1660, natural philosophers had justified its existence in terms of usefulness, such as improved national industry and navigation and, in the wake of the English civil war, a way to battle potentially socially destabilizing superstition.[30] Into the eighteenth century, Newtonian mechanics had applications in industry and navigation, and promised to improve the business of entrepreneurs.[31] Furthermore, Newton's ideas were popularized in the public sphere as a way to separate him from scientific rivals, like Descartes and Leibnitz, and entrenched his authority within British natural philosophy. Moreover, it became fashionable for a growing middling-class to be cultivated in the tenets of natural philosophy, not necessarily on the

[30] See Thomas Sprat, *The History of the Royal Society of London, For the Improving of Natural Knowledge*, (London: 1667); also the significant study of public science and it utilitarian roots Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Knowledge, 1660-1750,* (Cambridge, England: Cambridge University press, 1992),
[31] For the role of Newtonian mechanics in industry see Larry Stewart and Margaret C. Jacob, *Practical Matter: Newton's Science in the Service of Industry and Empire, 1687-1851,* (Cambridge Mass: Harvard University Press, 2004).

merit of practical utility, but rather to emulate the cultured upper classes.[32] Natural philosophy, as a result of this public exposure and interest, became a commodified good within a burgeoning knowledge market. Itinerant lecturers realized that there was money to be made demonstrating natural philosophy to paying audiences both interested in the practical lessons and enticed by novel displays. This market became more competitive and it became difficult to separate instruction from entertainment.[33] At times lectures produced public displays that were nothing more than wondrous spectacles aimed more at providing an impressive show than any meaningful instruction. However, those who could gain philosophic credibility, usually through membership of well established institutions like the Royal Society, could use that standing as a way to delineate themselves as legitimate natural philosophers as opposed to dubious charlatans and projectors more concerned with profit than disseminating philosophical knowledge.

The philosophic elite of the Royal Society were viewed as legitimate sources of natural knowledge. They seemingly embodied the traditional gentlemanly ideal of pursuing natural philosophy without concern for personal gain, but rather to reveal the laws of nature as an intellectually-rewarding endeavor or for the genuine dissemination of sound useful knowledge. Noted fellow and experimenter of the Royal Society, John T. Desaguliers, disseminated Newtonian philosophy to paying audiences. He justified doing so by maintaining that a public well versed in natural philosophy could spot fakes and

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[32] On natural philosophy as a form of upper class emulation see, Jan Golinski, “Barometers of Change: Meteorological Instruments as Machines of Enlightenment,” in William Clark, Jan Golinski, and Simon Schaffer, eds. *The Sciences in Enlightened Europe*, (Chicago: University of Chicago Press, 1999), 69-93; James A Bennett, “Shopping for Instruments in Paris and London,” in *Merchants and Marvels: Commerce, Science, and Art in Early Modern Europe*, Pamela H. Smith and Paula Findlen, eds. (New York: Routledge, 2002); and Eric Robinson, “Eighteenth Century Commerce and Fashion: Mathew Boulton’s Marketing Techniques” *Economic History Review* 14 (1963): 39-60.
[33] Stewart, *The Rise of Public Science*, 123-126.

ruinous projectors.[34] By employing rhetoric that suggested he lectured to paying audiences not for personal benefit, but to promote useful knowledge for the greater public good, he avoided the ire of his philosophical colleagues and yet still made a significant profit. Examining public lecturers in this market reveals a tension between the members of the philosophic elite and the potential for gain in the public marketplace. The ideal natural philosopher achieved philosophic credibility through acting the part of the disinterested observer, yet that very philosophic standing could give the public lecturer a marked advantage in the competitive public market filled with others lacking similar credentials. Several important histories, notably Larry Stewart's *The Rise of Public Science*, examine how natural philosophers employed rhetoric involving social good and utility to justify public lecturing. My project, intends to cover similar ground but through the lens of the philosophic instrument-maker, whose labour was essential to the development of the apparatus of natural knowledge production, dissemination, and replication. Like the itinerant lecturer, the philosophic instrument-maker utilized philosophical rhetoric and also marketed and protected instruments in an attempt to garner philosophic standing in order to enhance their business potential in the public market.

Methodology

This thesis is heavily framed in the constructivist methodology as it assumes that the very legacy of the gentlemanly protocol and expectations, found in Robert Boyle's Royal Society of the late seventeenth-century, ironically influenced the way natural philosophy was disseminated in the growing public market of the eighteenth century. Instrument-makers permeated both the realms of the philosophic elite and the public

[34] Ibid., 126-128, 283.

market, as both spaces needed quality apparatus to perform and replicate experiments. Yet this middle ground placed the philosophic instrument-maker in a precarious position between two seemingly contradictory worlds. In general, most instrument-makers were craftsmen who sold the instruments of natural philosophy in order to earn a living.[35] Despite their profit-oriented motivations, instrument-makers often gained entry as members of the philosophic elite, and consequently, translated this standing into an advantage in the competitive public market. This presents an interesting paradox: how could the commercial instrument-maker, who was motivated contrary to the rules of engagement within the philosophic elite, gain admission to the philosophic world and use that standing to increase profits? The answers lie in the way they veiled their financial motivations through rhetoric and marketing strategies, which focused heavily on their role as disseminators of sound and useful knowledge and their participation in the practice of natural philosophy. The fact that instrument-makers employed sophisticated marketing strategies that focused heavily on their own reputations as credible scientific practitioners, illustrates that indeed the scholarly values of the late seventeenth-century gentlemanly philosopher influenced the make-up of the legitimate eighteenth-century natural philosopher, and directed the way instrument-makers sought credibility in the philosophic instrument market. This is specifically highlighted in the way many instrument-makers viewed the patent system, most notably by avoiding a patent's potential as a legally enforced tool of monopoly. Patents were thought by natural philosophers to have violated the spirit of scholarly openness expected of natural philosophy. Instead the instrument-maker often opted to employ patents as trademarks or

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[35] The Guild system underwent a decline and had difficulty policing the rapidly expanding instrument making market, see Larry Stewart, "Science, Instruments, and Guilds in Early-Modern Britain," *Early Science and Medicine* 10, no. 3 (2005): 394, 396-398.

branding mechanisms which separated their products from generic replicas, but did not prevent others from building philosophic instruments.[36]

Central to this project is the examination of philosophic instrument-makers' motivations and interactions, which provide an avenue for understanding the complexities of the eighteenth-century natural knowledge market. These individuals existed in the worlds of the philosophic elite and the larger public sphere, and by examining their activities one can understand how these realms interrelated. This project intends to examine how instrument-makers sought to balance the expectations of the philosophic elite and the realities of the commercial marketplace. By doing this I hope to uncover the role of philosophic credibility in the instrument trade, and how this influenced the dissemination of natural philosophy among the eighteenth-century public. Moreover, I intend to reveal the constructivist tenet, that scientific knowledge is directed by external and human actions, by studying activities of the instrument-maker who, through marketing strategies, both reacted to and directed consumer fashion in the philosophic instrument trade.

The second chapter of this thesis examines the life of Benjamin Martin, who early in his career was an author and itinerant lecturer on natural philosophy, and later became an instrument-maker in London. Martin understood that a fellowship to the Royal Society of London would benefit his business as an itinerant lecturer, as his audiences often rebuked him for not possessing one.[37] Finding himself at a disadvantage in the lecturing market, he attempted to persuade the Society's President, Sir Hans Sloane, to put him up

[36] Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System, 1660-1800*, (Cambridge: Cambridge University Press, 1988), 88-89,; also Mario Biagioli, "From Print to Patents: Living on Instruments in Early Modern Europe," *History of Science*, 44 (2006): 6.
[37] Millburn, *Benjamin Martin*, 35-38.

for fellowship. However this antagonized Sloane as it appeared Martin wanted only to use a fellowship to enhance his business, a significant violation of the gentlemanly protocol that governed the Society, and he was duly denied admittance.[38] Despite the lack of formal philosophic status and trade skill, he developed an instrument-making business on Fleet Street in 1756. Without a fellowship to the Royal Society, he had difficulty establishing lucrative patrons among the philosophic elite. Nonetheless, Martin was a gifted author, up to date in philosophical matters, and published easy-to-read books on natural philosophy which he directed to the general public. These publications were the heart of a sophisticated marketing strategy, with which he instructed the public on how to perform amusing philosophical experiments with inexpensive instruments found in his shop. [39] Martin's well-informed publications, and his penchant for underselling competitors, attracted a steady clientele among a broad public increasingly interested in trying experimental philosophy. This demonstrates that indeed a public market was vibrant by the middle of the eighteenth century. However, he went bankrupt in 1782 partly because his lack of formal philosophic credit restricted his business in an competitive popular instrument market, and his shortcomings in craft skill hindered his ability to innovate according to consumer fashion, or corner the market with a unique product. His successful competitors, especially craftsmen like John Dollond and Edward Nairne, gained formal philosophic credit within the scientific community and won steady patronage through the philosophic networks they developed. They were not, therefore, limited in the public market. Moreover, the philosophic credit that these instrument-

[38] Ibid.; also John R. Millburn, "Benjamin Martin and the Royal Society," *Notes and Records of the Royal Society of London* 28, no.1 (1973): 17-19.
[39] John R. Millburn, *Benjamin Martin – Author, Instrument-Maker, and 'Country Showman'*, (Leyden: Noordhoff International Publishing, 1976), 68-79.

makers gained allowed them to stand out in the public market and enjoy an advantage over rival instrument-makers, because the products they sold were perceived as credible among consumers.[40]

The third chapter looks at how successful instrument-makers resolved the tension between, on the one hand, achieving and maintaining philosophic standing and, on the other, selling instruments for profit in the public market. John Dollond, for example, in 1758 gained the trust of the Fellows the Royal Society by solving the problem of chromatic aberration in telescopes. That year he was awarded the Copley medal, the Royal Society's highest honour, and a fellowship in 1761.[41] He gained these accolades partially on the weight of discovery, but also, because he found achromaticity through careful experimentation and engagement within the philosophic community – essentially playing the part of the ideal natural philosopher. Interestingly, he managed to maintain his philosophic credibility, despite patenting and selling achromatic lenses for profit. Patents were then viewed as especially offensive among natural philosophers as they were instruments of monopoly, thereby violating both scholarly openness and disinterestedness valued within philosophic circles. Dollond avoided these problems by using his patent not as a legal instrument, but rather as a brand, injecting his priority and the significance of his discovery into a distinguished original product in a market filled with inferior instruments.[42] Upon Dollond's death, his son and business partner, Peter, activated the patent's legal potential and exploited a monopoly on achromatic lens production. As a consequence, he antagonized his fellow instrument-makers who no

[40] For accounts of Dollond and Nairne see Paola Bertucci, "A Philosophical Business: Edward Nairne and the Patent Medical Electrical Machine (1782)," *History of Technology* 23, (2001): 41-58; and Richard Sorrenson, "Dollond & Son's Pursuit of Achromaticity, 1758-1789," *History of Science* 39 (2001): 31-55.
[41] Sorrenson, 35.
[42] MacLeod, *Inventing the Industrial Revolution*, 85; Also Mario Biagioli, 6.

longer could make the sought-after lenses. Furthermore, he attracted the ire of the philosophic community for monopolizing production and therefore, restricting the exchange of the instruments of philosophic dissemination.[43]

While Dollond's account frames how the instrument-maker's actions were influenced by the expectations of the philosophic elite, there were ways to balance them with the conditions of the market. The final chapter follows a similar line, examining how the instrument-maker was directed by the values of the philosophic sphere. However, Edward Nairne's path is slightly different in that he gained philosophic standing quite early in his career, as he obtained a fellowship to the Royal Society in 1776, due to both his high quality electrical machines and his contributions to electrical theory.[44] Nairne became a respected authority in matters of electrical machine construction and theory, and developed an international philosophical network and clientele. By the 1780s a public medico-electric market had also emerged. In response, Nairne who largely sold to top practitioners in the philosophic market, developed and patented a medical electrical machine for the general public.[45] His fellowship to the Royal Society was an important mark of credibility in the un-policed electrical market filled with charlatans and dubious practitioners. Furthermore, he employed a patenting strategy similar to John Dollond, using it as a seal of his authority as a quality instrument-maker and reputable natural philosopher. Critically, in addition to marketing his machine as a healing device, he also stressed its experimental capability. By doing this he affirmed to the public that his machine was a legitimate piece of equipment grounded on philosophical principles,

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[43] Sorrenson, 40-41; also, MacLeod, *Inventing the Industrial Revolution*, 73-74.
[44] Bertucci, 43-45.
[45] Ibid.,

specifically important in a medical market rife with dubious healing products.[46] However, by focusing on the dual role of the machine he also justified his actions within the marketplace in terms of both healing the bodies and improving the minds of the public, and therefore, maintained his standing among his philosophical peers as he appeared not to be primarily motivated by personal profit.

This examination of the philosophic instrument-making industry reveals that the archetype of the gentlemanly philosopher was an important signifier of authority in the un-policed public market. Instrument-makers sought this philosophic credit as a way to separate themselves from rivals and improve their business among clients of all social standing. It is within this eighteenth-century market that one can see the antecedents of the relationship between scientific authority and monetary concerns in our contemporary commercialized world of science. In this world, scientific programs are directed by both authoritative experts in search of understanding nature, but also by corporate and government agencies concerned with practical scientific applications and potential commercial profitability.

[46] Ibid., 51.

CHAPTER TWO

Benjamin Martin

The life of Benjamin Martin, author, itinerant lecturer, and philosophic instrument-maker, provides an instructive example of the nature of eighteenth-century public science, and the dynamics of the English philosophic instrument trade. Martin's career reveals that in the eighteenth century a tension existed between the philosophic elite of the Royal Society of London and practitioners who sold natural philosophy as a product in the public market. These practitioners, such as itinerant lecturers and scientific instrument-makers, struggled to gain legitimacy while existing precariously between the contradictory moral framework of natural philosophy and the profit oriented reality of the market.[47] Martin, for example, sought a fellowship to the Royal Society partly in order to improve his standing within the philosophic community, and to likewise increase his credibility among paying audiences interested in attending his lectures. However, he was denied membership by the fellows because he overtly showed interested in using a prestigious Royal Society fellowship for profit – a major violation of the 'gentlemanly' values upon which the Royal Society was founded.[48]

It is clear that Martin's career was significantly limited without a fellowship to the Royal Society. By the 1750s the itinerant lecturing market had become saturated and Martin was no longer competitive within it.[49] In 1756 he gave up lecturing full-time and established an instrument-making business on London's Fleet Street (situated near the

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[47] Mario Biagioli, "From Print to Patents: Living on Instruments in Early Modern Europe," *History of Science* 44 (2006): 1.
[48] John R. Millburn, *Benjamin Martin – Author, Instrument-Maker, and 'Country Showman'*, (Leyden: Noordhoff International Publishing, 1976), 35-36; John R. Millburn, "Benjamin Martin and the Royal Society," *Notes and Records of the Royal Society of London* 28, no. 1 (1973): 15, 18; and also, Simon Schaffer, "The Consuming Flame: Electrical Showmen and Tory Mystics in the World of Goods," in *Consumption and the World of Goods*, John Brewer and Roy Porter, eds. (London: Routledge, 1993), 498.
[49] Millburn, *Benjamin Martin*, 85.

Royal Society), which he maintained until it succumbed to bankruptcy in 1782. The longevity of the business, and also its eventual bankruptcy, are both telling of the nature of the philosophic instrument trade at the time. Martin was not a skilled craftsman and had not developed any significantly novel inventions.[50] Nonetheless, he was an innovative marketing strategist and used his publications on natural philosophy, which were directed at all levels of society, to advertise the instruments he sold at his shop. Martin understood that the broader public, beyond the aristocracy, was increasingly interested in learning and engaging with natural philosophy. Consequently, he made a comfortable living meeting the growing demand for inexpensive instruments affordable to the common purse.

Despite the longevity of Martin's business, in 1782 he suffered a devastating bankruptcy. The failure of his instrument-making shop can be attributed to his inability to garner a reliable and long-term commission, limiting him to the highly contested public instrument market. He therefore focused primarily on selling popular philosophical instruments, books, spectacles, and some navigation instruments.[51] Though he managed to eke out a living selling to a wider public, he was constantly threatened by the fickleness of consumer fashion. He had never obtained a long term commission as had his rival George Adams Sr. in supplying navigation instruments to the Office of Ordinance.[52] It seems that most successful instrument-makers at this time occupied niche markets because of technical expertise or close connection to natural philosophers.

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[50] Martin did corner the globe market until 1766 when he obtained the Senex globe patterns; however, this was a case of fortune and not technical ability.

[51] For an extensive catalogue of Martin's instruments for sale, see, for example, Benjamin Martin, *The Theory of Comets Illustrated, in Four Parts*, (London: 1757), 58-60.

[52] John R. Millburn. *Adams of Fleet Street, Instrument-makers to King George III*, (Aldershot: Ashgate, 2000), 52-54.

Consequently, they had the skill and/or reputation, which was useful in selling to both natural philosophers and the public market, in which philosophic credibility translated into a competitive advantage. Furthermore, philosophic connection and skill was useful for obtaining a steady income from stable commissions from government entities or significant patrons.[53] A close examination of his life and business practices reveals how he violated the comportment of the philosophic community, attracted the ire and suspicion of the scientific elite, and consequently, harmed his chances of sustaining his business through their invaluable connections.

Early Career, Profit, and the Pursuit of Philosophic Credibility

Little is known about the early life of Benjamin Martin. He was born in 1704 in a rural setting near the village of Worplesdon, and as a young man he received a significant inheritance which provided him with the means to study natural philosophy. He was primarily self-taught and became well versed in the scientific literature of the time, reading, among others, the works of Francis Bacon, Robert Boyle, Isaac Newton, Edmond Halley, Samuel Clarke, Rene Descartes, and John Theophilus Desaguliers.[54] In the 1730s, having acquired a proficiency in natural philosophy, he began a career as a public educator. Around 1734 he opened a boarding school at Chichester, teaching youth the basic precepts of mathematics and natural philosophy.[55] It is not clear that Martin's school was successful, but its existence was short lived. Despite this, he established himself as a capable author, publishing several textbooks in the 1730s covering mathematics and natural philosophy.

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[53] John Dollond and Edward Nairne occupied specialized markets with the achromatic lens and cylindrical friction electrical machine respectively. George Adams procured a steady income through the Office of Ordinance, and the merit of his craft skill.
[54] Millburn, *Benjamin Martin*, 5, 16.
[55] Ibid., 11.

It seems that Martin's own self-education motivated him to publish books aimed at the general public. He felt that, with the appropriate approach, the average person was capable of studying and understanding natural philosophy. He outlined his philosophy on education quite clearly in a note to his subscribers in *Bibliotheca Technologica, or, a Philological Library of Literary Arts and Sciences* (1737), stating "…Learning is the essential and distinguishing *Characteristic* of *Man*, and is the proper boundary between *Human* and *Brute* Nature." [56] "Men, in general" he states optimistically, "are not so much wanting in *capacity* as in *time* and *pocket*, for gaining literary accomplishments."[57] Similarly, in the preface of his most successful book, *The Philosophical Grammar; being a View of the Present State of Experimented Physiology, or Natural Philosophy* (1735), a general survey of natural philosophy, he maintained that most literature on the subject was:

> …designed for the learned, so only scholars are capable of understanding them …The most famous pieces of this kind are, some of them, too expensive for the purse of the public…Some, or most of them, are filled with mathematical and symbolic demonstration, schemes, characters, that it surprises and repells (sic) the plain unlearned (or rather ungeometrical) reader from any perusal of them; who yet is capable of understanding a good part of philosophy, when treated in a plain, evident, familiar way.[58]

Furthermore, he believed that the public could understand and benefit from natural philosophy if it was introduced "…so plain, natural, and easy as to be understood with pleasure; and yet, so general and copious, that nothing useful might be wanting."[59] Martin understood the potential of the public market, and specifically priced his

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[56] Benjamin Martin, *Bibliotheca Technologica, or, a Philological Library of Literary Arts and Sciences*, (London, 1737), i.
[57] Ibid., iii.
[58] Quoted in Millburn, *Benjamin Martin*, 14; Martin's *The Philosophical Grammar* was by far his most popular book and reached an eighth edition. This is telling of the popularity of natural philosophy in general as the public sought an easy to read survey of the sciences.
[59] Benjamin Martin, *The Philosophical Grammar; being a View of the Present State of Experimented Physiology, or Natural Philosophy*. (London: 1735), vi.

publications, lectures, and later, his instruments to suit a modest budget. He often commented on the importance of producing affordable literature because it would facilitate in the dissemination of natural philosophy.[60]

Martin's beliefs regarding the ability of the common sort to understand natural philosophy is illustrative of the state of public science at that time. He was a devout Newtonian who believed the universe could be understood in terms of laws, contrived by a rational God, which could be made known through empirical experiment. Furthermore, like many eighteenth-century Newtonians, Martin understood the value of natural philosophy, and in fact nature, in terms of morality, utility, and public good. He claims that the "…greatest use of natural philosophy is this, that it naturally inspires us with religious and devout dispositions of mind…and elevates us to the pitch of the most rational kind of worship…"[61] Essentially, understanding God's work through experimental natural philosophy was the most effective way to comprehend God. Furthermore, he felt, as did many eighteenth-century writers, that humans were special among God's creations because they possess a level of intelligence beyond that of any other animal. To neglect this faculty was a waste of human potential and perhaps even a betrayal to God. Consequently, he viewed natural philosophy as extremely important because it "…is the only source of all true glory and greatness in the human mind, and the ultimate perfection of our nature."[62] Learning was a powerful means of self-improvement, and for Martin, the utmost exercise of humanity. Significantly, this

[60] Millburn, *Benjamin Martin*, 13.
[61] Martin, *The Philosophical Grammar*, xii.
[62] Benjamin Martin, *A Panegyrick on the Newtonian Philosophy. Shewing the Nature and Dignity of the Science*, (London: 1749), 11.

potential to learn was present in all humans despite social status, occupation, or wealth, and therefore, he felt that all levels of society should have access to educational materials.

Aside from providential and moral utility, Martin stressed the practical value of natural philosophy within everyday contexts. He states, for example, that through natural philosophy one can explain:

> The *animal Oeconomy*, the Nature of *Vegetation*, the *Culture of Plants*, the *Improvement of Land*, the *Manufacture of Goods*, and meliorating the methods of procuring and preserving our *Bread and our Meat* our *Beer and our Wine*.[63]

He concludes that "…a man in every vocation … has occasion enough for the assistance of this Science," and maintains that "…no artist can execute and succeed so well, as he that keeps close to nature, and best understands her operations."[64] Natural philosophy had seemingly limitless application and promised improvement in areas ranging from navigation, mechanics, and hydraulics to gunnery, commerce, and medicine.[65] For Martin and other disseminators, the utility of natural philosophy was essential for justifying its practice.

This rhetoric, nonetheless, was not new. After the establishment of the Royal Society in 1660, the fellows had sought to legitimize experimental natural philosophy by claiming its inherent usefulness.[66] However, by the eighteenth century, the usefulness of scientific knowledge was increasingly transformed into a desirable commodity among an interested public. During the first quarter of the eighteenth century Newtonian popularizers such as John Harris, James Hodgson, Francis Hauksbee, William Whiston,

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[63] Ibid., 44.
[64] Ibid.
[65] Ibid., 37-39, 42-43.
[66] See Thomas Sprat, *The History of the Royal Society of London, For the Improving of Natural Knowledge*, (London: 1667); also Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Philosophy in Newtonian Britain, 1660-1750*, (Cambridge England: Cambridge University Press, 1992), 16, 20-21.

and later John T. Desaguliers, lectured on and demonstrated natural philosophy through experiment to a paying public that was not only curious about the natural world, but also in the practical application of Newton's mechanics in commerce.[67] By the end of the first quarter of the eighteenth century, the market for natural philosophy continued to flourish in London and into the English Provinces. Increasingly authors, itinerant lecturers, and instrument-makers realized they could make a living meeting the demand in the public knowledge market. However, as the market grew, a real anxiety emerged, especially among the scientific elite, over the morality of pandering to the public.

Several concerns emerged. First, there were fears that charlatans, pretenders, and projectors would prey on the ignorance of many through dazzling demonstrations or false projects, claimed to be supported by legitimate natural philosophy. Desaguliers anticipated this threat and maintained that a public well versed in natural philosophy would be capable of spotting fakes.[68] Such was a practical justification for sound public lecturing because it supported the good of society. However, a second more complicated question addressed the very morality of selling natural philosophy for a profit. This concern was a product of the transition of natural philosophy from an largely gentlemanly practice within the Royal Society in the seventeenth-century, to its commodification in the open public market during the eighteenth. In the Royal Society of the seventeenth-century, the acceptance or denial of what constituted factual natural philosophy was determined by the perceived validity of an experiment viewed and discussed by the

[67] Margaret C. Jacob and Larry Stewart, *Practical Matter: Newton's Science in the Service of Industry and Empire, 1687-1851*, (Cambridge Mass.: Harvard University Press), 117; also Stewart, *The Rise of Public* Science, 111-117.
[68] Stewart, *The Rise of Public Science*, 126.

fellows.[69] The members of this group, largely privileged gentlemen, were deemed worthy judges of 'matters of fact,' because they were viewed as uninterested (unlike a paid lecturer) and concerned only with finding truth.[70] The idealized portrait of the uninterested scientific practitioner remained present within the Royal Society well into the eighteenth century. Lecturers and instrument-makers who appeared to be motivated by profit and not by the interest of truth and social good, were often chastised by the scientific elite.

The rhetoric found in Martin's publications during the 1730s strongly focused on the moral and social benefits associated with natural philosophy. Furthermore, a close examination of his life reveals that he did have a genuine concern for natural philosophy and the usefulness of knowledge. Nonetheless, he was also clearly motivated to make a personal profit from the dissemination of natural philosophy. By the end of 1738 Martin had started a career as an itinerant lecturer, traveling throughout the English countryside. He sought a fellowship to the Royal Society, a prestigious symbol of philosophic credibility, in order to attract larger audiences to his lectures. In December he communicated with Sir Hans Sloane, President of the Royal Society, asking permission to dedicate an astronomical print in his name. Sloane agreed to this, and in a subsequent letter Martin graciously communicated his thanks.[71] In rhetoric favorable to the expectations of the Royal Society, Martin represented that:

> No person, I presume to say, can take greater pleasure or pains in ye pursuit of natural enquiries, especially those of ye microscope in which I have often met with such curious subjects and discoveries as I have not yet read of & of which I intend in time to give a printed acct: I believe I could now and then

[69] Steven Shapin, "The House of Experiment in Seventeenth-Century England," *Isis* 79, no.3 (September, 1988): 382.
[70] Ibid.
[71] Millburn, "Benjamin Martin and the Royal Society," 15-16.

> pro[vide] ye society with some curious and uncommon microscopic objects &c, if I knew they would be acceptable, & how to communicate them.[72]

Martin thus, portrayed himself as the archetypical natural philosopher, painstakingly observing nature for the sake of gaining empirical knowledge. Furthermore, he conveyed to Sloane that he was working with a microscope and producing novel discoveries which he was willing to communicate to the Royal Society.[73] Had Martin continued to communicate to the Royal Society in this way he may have eventually been granted admission to the Royal Society. In this letter, and even in his earlier educational publications, he conveyed the values and rhetoric of the ideal natural philosopher. Furthermore, he started to produce original contributions to natural philosophy. He was working on microscopy and in 1740 he produced his first original work, *A New and Compendious System of Optics,* which highlighted his own observations in the field.[74] However, by 1741 his posturing for admission to the Royal Society had taken a much more aggressive turn. Consequently, his motivations became much clearer to Sloane and the Fellows of the Royal Society.

In November of 1741 Martin wrote two similar letters to Sloane and to the well-connected fellow, the Duke of Richmond, asking to be considered for membership to the Royal Society. To Sloane he wrote:

> I have a family, & my chiefest dependence to maintain them, is by reading lectures on Nat. & Exp. philosophy, from town to town in ye country . . . whenever I come, I am constantly asked, *If I am a Fellow of ye R. Society?* And I as constantly find it no small disadvantage to say, no. I have therefore been advised and prevailed upon to apply for that honour, wh would give so great a sanction and be of such advantage to my profession…[75]

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[72] Quoted in Ibid., 16.
[73] Indeed Martin did produce a work on his microscopic observations. See *Micrographia Nova: or, New Treatises on the Microscope, and Microscopic Objects* . . . (London: 1742).
[74] Millburn, *Benjamin Martin*, 28-29.
[75] Martin quoted in Millburn, "Benjamin Martin and the Royal Society," 17.

Martin's intentions were very clear - he saw a fellowship as a means to improve his credibility among the public, and could entice a larger paying audience to his lectures. He then assured Sloane that "…no man takes greater delight in studies of philosophy, nor taken greater pains to improve ye science in general," no doubt in an attempt to maintain his philosophic integrity.[76] At this time he had begun to dabble in instrument-making, and in a move to curry favor, he offered an air pump to Sloane on the condition of his admission.[77]

Martin's lack of tact did not sit well with Sloane who conveyed his feelings to the Duke of Richmond. There are no known extant copies of Sloane's letter to the Duke, nor the latter's to Martin. However, one can sense Sloane's disapproval from a letter Martin wrote to him 1741 where he apologizes for writing the "…Letter, which (I am told) you could not think honowrable (sic) & therefore was not construed so much in my favour."[78] Furthermore, with respect to his application for fellowship he maintained that:

> …I durst not attempt it with any but ye President and his Grace ye Duke of Richmond, with whom I presumed I could speak as freely as to my friends and patrons, & therefore added to ye motion of honour that of interest, which I was not aware would render me suspicious of seeking such an honourary post with a mercenary view…[79]

It is clear that Sloane did not appreciate Martin's plan to make use of a fellowship. This clearly reflects the commonly held concept, within the Royal Society, that natural philosophy was justly practiced so long as it was motivated foremost by knowledge, and not self-interest. When Martin wrote his apology letter, Sloane was no longer President of the Royal Society, and on the same day he wrote his apology to Sloan, he wrote another

[76] Ibid.
[77] Ibid.; also Schaffer, 498.
[78] Millburn, "Benjamin Martin and the Royal Society," 18-19.
[79] Ibid., 19.

letter to the new President Martin Folkes, congratulating him on his post and again requested to be admitted to the Society.[80] Martin must have felt more confident of his chances of admission under Folkes. The new President liked Martin's pocket microscopes, made in his spare time, and Martin had also dedicated his *A New and Compendious System of Optics* to him.[81]

Despite this relationship, Martin was not granted admission to the Royal Society. It is likely that he was not allowed admission because he had not produced a significant body of original work, save *A New and Compendious System of Optics,* and later his *Micrographia Nova*. As John Millburn observes, it is interesting to compare Martin's relationship with the Royal Society with that of his contemporary, the itinerant lecturer, James Ferguson. Ferguson applied for admission to the Royal Society after twenty-years of building a reputation as a lecturer, demonstrating apparatus for the fellows, contributing novel scientific observations to *The Philosophical Transactions*, and producing the significant *Astronomy Explained upon Sir Isaac Newton's Principles* in 1756.[82] Essentially, Ferguson gained the trust of the scientific community through his proven dedication and contributions to natural philosophy. Martin did the inverse, and attracted their suspicion by abusing the rules of comportment within the Royal Society. Consequently, Martin's career was characterized by a continuous struggle to find legitimacy within the scientific community.

Philosophic Credibility Challenged: Martin vs. John Freke

Despite not possessing a fellowship in the Royal Society, Martin continued to lecture throughout the countryside, supplementing his income by publishing lectures and

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[80] Millburn, *Benjamin Martin*, 37.
[81] Ibid., 29.
[82] Millburn, "Benjamin Martin and the Royal Society," 21-22.

other works on natural philosophy. During the 1740s itinerant lecturing continued to grow as the public demand for natural philosophy remained strong. In an attempt to distinguish himself from his rivals, Martin often blatantly criticized their work or even personal character. Often he charged competitors with being "…ignorant and empirical pretenders…," who unlike himself, did not base their work on solid scientific principles.[83] By the 1740s electricity was one increasingly popular area of investigation, and its mysterious characteristics baffled natural philosophers and intrigued the public mind. Even Martin admitted that he did not know the cause of electricity; however, he felt it must be based on the tenets of Newtonian mechanics.[84] In 1746, Martin had initiated a bitter pamphlet war with the respected surgeon and FRS John Freke, whom he accused of having "…no more notion of the nature and cause of electricity, than he has of the elements of modern philosophy."[85] The two men held highly different views on the much disputed nature of electricity. Freke maintained that experimental philosophers were wrong to think that their apparatus actually generated electricity, but rather that the electrical machines collected it from the air.[86] As a surgeon he connected electricity to physiology, reasoning that "…the air, which is esteem'd the *Pabulum Vitae*, from its rubefying the blood of all animals in respiration, seems to be universally impregnated with this fire."[87] The idea that air was the main source of electrical fire ran opposite to Martin's belief that experimental electrical machines actually produced the electricity within their glass tubes. Martin attacked Freke and questioned his competence. However,

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[83] Benjamin Martin. *A Course of Lectures in Natural and Experimental Philosophy, Geography and Astronomy: in which the Properties, Affections, and Phænomena of* . . . (Reading: 1743), i.
[84] Ibid., 53.
[85] Martin quoted in Millburn, *Benjamin Martin*, 55.
[86] Schaffer, 506.
[87] John Freke, *An Essay to Shew the Cause of Electricity; and why some Things are Non-Electricable. In which is also Consider'd its Influence in the Blasts on* . . . 2nd ed., (London: 1746), 3-4.

the theoretical debate soon expanded into one of philosophic credibility and Martin's personal interests were addressed with more concern than his actual theory.

In 1746 Martin had been nearly ready to publish his *An Essay on Electricity: being an Enquiry into the Nature, Cause and Properties thereof, on the Principles of Sir Isaac Newton's Theory of* . . . when Freke had completed his own book on the topic. Martin was concerned that this rival publication would hamper his book sales. Upon reading it, Martin viciously criticized both Freke's views on electricity and his competence as a man of science. Freke condescendingly replied to Martin in the second edition of his *An Essay to Shew the Cause of Electricity; and why some Things are Non-Electricable. In which is also Consider'd its Influence in the Blasts on* . . ., by insinuating Martin's attack had little to do with theory, but rather, more to promote his own book:

> …If this person be poor, and did it for gain, I heartily pity him. He owns he was much affrighted, when he heard of my publishing this piece, because of the hard fate, he says, of his booksellers…I believe there are more answers to books written to pay a landlady, or an ale-house score, than from any other cause… [88]

Freke clearly viewed Martin's profiteering as unethical as he wrote his own *Essay* ". . . not for any gain to myself, but the pleasure of informing…"[89] Martin replied with the publication of *A Supplement: Containing Remarks on a Rhapsody of Adventures of a Modern Knight-Errant in Philosophy*, by brusquely charging Freke with being "…what we properly call a pure ignoramus…" and attempted to justify that showing lectures for money was not a dishonest endeavour if employed according to just scientific principles.[90]

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[88] Freke quoted in Millburn, *Benjamin Martin*, 56.
[89] Freke, vi.
[90] Millburn, *Benjamin Martin*, 56-57.

This exchange between the two is very telling of what constituted philosophical credibility. Martin's abuse of a Fellow of the Royal Society attracted some bad press on his part, and perhaps extinguished any chance of admission to the Royal Society. *The Gentleman's Magazine* summed it up, portraying Martin rather unkindly, stating that his treatment of Freke in such an "ungenteel manner…without the least provocation…greatly exposes himself."[91] The editor implied that Martin's attack was motivated out of concern for book sales, rather than disseminating natural philosophy. Simon Schaffer feels that the discourse between Martin and Freke is descriptive of the moral concerns involved with profiting from electrical demonstrations at that time. In Freke's opinion Martin was abusing electricity, a God-given element of life, for the purpose of entertainment and profit.[92] However, if one considers Martin's failed campaign to gain admission to the Royal Society and his altercation with Freke together, it is clear that he violated a common set of values that existed among the larger community of natural philosophers in general. That is, that natural philosophy ultimately sought unbiased truth, and produced numerous useful consequences. The ideal utility of natural philosophy was to be a benefit and improvement for the larger society. Wealth as an outcome itself was not frowned upon, so long as it involved increasing the commerce of a nation or improving the state of general society. However, there was a broad view that projectors, stock jobbers, charlatans, and quacks became a real threat and abused natural philosophy for personal gain.[93] The rhetoric of social good and public utility was important for legitimacy and an essential norm within the circles of natural philosophy. Martin appeared to be sensitive to this rhetoric early in his career as an author: he was making a personal profit selling

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[91] Schaffer, 501.
[92] Ibid., 494.
[93] Jacob and Stewart, 46-47.

books on natural philosophy, yet he claimed that it was for the sake of improving the public mind. However, his attempt to gain fellowship at Royal Society and his attack on Freke, were both poorly calculated. Consequently, he attracted the suspicion of some influential members of the scientific community and ruined his chances of enjoying the prestige and benefits of a FRS.

Selling and Marketing Philosophic Instruments

By 1756 Martin focused on the establishing an instrument-making business on London's Fleet Street. It is difficult to determine exactly why he abandoned lecturing in the countryside. Millburn postulates that because of advancing age he may have sought less travel. Also, by this time, he was planning the publication of the *General Magazine*, a subscription-based periodical that ran successfully until 1764, which would have required him to be close to his publisher located in London.[94] Furthermore, the lecturing market in England was inundated, and without a FRS, he may not have been able to command large audiences in a competitive market. Although he was not a skilled craftsman he had some experience building and modifying simple scientific instruments early in his career, and managed to maintain a comfortable living until the last year of his life. The fact that Martin, a man with no background in the skilled trades, nor a FRS to attach to his name, survived in the instrument trade explains the popularity of affordable well-marketed instruments within the public sphere.[95] In his publications aimed at the general public, Martin cleverly marketed the instruments at attractive prices. Influenced by the rhetoric of improvement and utility spread by lecturers and disseminators, the

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[94] Millburn, *Benjamin Martin*, 64, 84-84.

[95] For a description of how instrument-makers sold instruments to the public through the accounts of select shoppers see James A Bennett. "Shopping for Instruments in Paris and London," in *Merchants and Marvels: Commerce, Science, and Art in Early Modern Europe,* Pamela H. Smith and Paula Findlen, eds. (New York: Routledge, 2002), 370-395.

public seemingly wanted instruments to replicate the experiments they had viewed. Martin did well to convince them to buy instruments in his shop because he claimed they were fairly priced, and based on the principles of natural philosophy. Nevertheless, he was neither able to corner and keep a niche market, nor establish any long term commissions as a means maintain a stable income. As a consequence, he fell victim to the fickle ebb and flow of the increasingly competitive public market, and died bankrupt in 1782.

By 1756 Fleet Street was already a major center of activity for instrument-makers and book sellers. Martin was closely situated to other notable instrument-makers such as Thomas Wright, George Adams Sr., James Short, Jesse Ramsden and Edward Nairne. Moreover, the Royal Society was located just off Fleet Street, in Crane Court, and was ideal location for the instrument-maker hoping to gain patronage from fellows.[96] Martin had established his business at a time when instruments used in natural philosophy were becoming very popular, and there was a sufficient market demand for him to earn a living. Moreover, the instrument trade was un-policed by guilds, and therefore, an unskilled maker like Martin was free to function as he desired.[97] He used his publications as a platform for self-promotion and implemented an aggressive marketing strategy that involved puffing his products, while criticizing and underselling his competitors.

Martin sold many philosophic instruments, including a range of telescopes, microscopes, planetariums, air pumps, barometers, some navigation tools, and eventually celestial globes.[98] The first publication he produced while operating his Fleet Street

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[96] Millburn, *Benjamin Martin*, 88-89.
[97] Larry Stewart, "Science, Instruments, and Guilds in Early-Modern Britain." *Early Science and Medicine* 10, no. 3 (2005): 394, 396-398.
[98] Millburn, *Benjamin Martin*, 90, 95.

business was *An Essay on Visual Glasses (vulgarly Called Spectacles),* within which he argued that the spectacles he made were superior to others because they were designed according to Newton's *Opticks*. Newton had postulated that the color violet was composed of the smallest particles and Martin fitted his spectacles with violet coloured lenses, assuming that they were the easiest on the eye. [99] By doing this Martin injected philosophic legitimacy into his unique lenses as they appeared to be founded on Newtonian authority. As a consequence, these lenses were one of his best selling items throughout his instrument-making career.[100]

Martin often also resorted to denigrating his competitors as 'un-philosophical,' in order to protect his sales of his Senex globes. The globes were originally developed by John Senex, the reputable Geographer to the Queen, and were the most detailed and sought after celestial and terrestrial globes at the time. It appears that at some point after Senex's death in 1740 Martin became the sole supplier of the globes and enjoyed a monopoly on their sale.[101] In 1758 he reacted to Samuel Dunn's planispheres, a cost effective alternative to the Senex globes. Martin responded in *An Essay on the Nature and Superior use of Globes, in Conveying the First Principles of Geography and Astronomy to the Minds of Youth; also a* . . . first by asserting that he had "…not been actuated by any other motive than the PUBLIC GOOD" and that "No man has been more anxious to make the rugged paths to knowledge plain and easy. . ."[102] He then described the importance of proper and accurate equipment necessary for learning geography,

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[99]Ibid., 93.
[100] Ibid., 94.
[101] Ibid., 102.
[102] Benjamin Martin, *An Essay on the Nature and Superior use of Globes, in Conveying the First Principles of Geography and Astronomy to the Minds of Youth*. . . (London: 1758), i.

especially "…by means of the *terrestrial* and *celestial globes*."[103] An accurate globe, like the famous Senex variety, provided one with the best opportunity to understand geography and, ultimately, principles of navigation. With Dunn in mind, Martin claimed "…*planispheres*," conversely, "are very imperfect and unnatural, and can give no correct notions of this science."[104] Martin's message to the public was clear: only by using high-quality globes, like his Senex globes, could one learn properly about geography; imperfect planispheres like the ones Dunn sold were inaccurate, inferior, and, did not promote proper learning.

Again in 1766, Martin's globe sales were threatened by George Adams senior's own set of educational globes. Adams printed *A Treatise Describing and Explaining the Construction and Use of New Celestial and Terrestrial Globes* to explain the novel features of the new devices.[105] Martin responded fiercely to Adams' publication in an *Appendix to the Description and Use of the Globes*, where he not only derided the construction of the new globes, and Adams' competence as an instrument-maker, but even his writing style. First, Martin complained that the new globes were sold "…at an excessive price..." implying that the public would be buying an inferior product at a greater cost than the Senex globe.[106] He also charged, with some merit, that the construction of his rival's globes were less effective for measurement and scientific accuracy, and he listed seventeen other flaws in the new globes.[107] But Martin had a major hurdle he had not faced with Dunn, as Adams was commissioned as mathematical

[103] Ibid., 5.
[104] Ibid., 7.
[105] Millburn, *Benjamin Martin*, 139.
[106] John. R Millburn, *Adams of Fleet Street, Instrument-makers to King George III*, (Aldershot: Ashgate, 2000), 123.
[107] Millburn, *Benjamin Martin*, 138-139.

instrument-maker to George III. By denigrating the new globes, Adams felt fit "…to acquaint his Majesty that he has made these globes less defective in their construction."[108] Even if the new globes were of lesser quality compared to his own, Martin felt that Adams had an unfair marketing advantage with his connection to the King. There may be some truth in this as Adams's globes were fundamentally less usable than the Senex variety because their brass supports inhibited accurate measurement. Still they captured the market after 1766, and even today, are sought after items at auction because of the famous Adams name.[109] On a more personal level, Martin criticized Adams' ability to write and even charged him with plagiarism. He pointed out grammatical errors and ambiguous terms in the *Treatises* in an attempt to sully Adams' competence. Furthermore, he claimed Adams had plagiarized some terms found in his catalogue, again in an attempt to challenge Adams' credibility.[110]

Adams did not respond to Martin's *Appendix*. According to the biographer John Millburn, it was probably because Adams had no need to – he was comfortable with his prestigious appointment as instrument-maker to the King, and commissions with the Office of Ordnance and the Royal Mathematical School.[111] Adams did not need to rely on an aggressive marketing strategy because he had been an established instrument-maker since the 1730s. He had several additional streams of revenue through his commissions, and he could use these appointments as a form of prestigious self-promotion and credibility within the public market. Martin, on the other hand, needed to aggressively challenge his rivals in order to convince the public to buy his products because he had

[108] Benjamin Martin, *Appendix to the Description and Use of the Globes*, (London: 1766), 10.
[109] Millburn, *Adams of Fleet Street*, 124; also Millburn, *Benjamin Martin*, 139.
[110] Millburn, *Adams of Fleet Street*, 124.
[111] Ibid.

few other opportunities. He was viewed with suspicion by many in the Royal Society, and his lack of craft skill made it difficult to produce high-end or novel instruments that could have cornered a market. However, it was a fortuitous time for him because the public was increasingly exposed to and interested in experimental philosophy, and as a capable author on matters of natural philosophy, he was able to convince readers to buy his instruments through his publications.

Perhaps Martin's most innovative marketing strategy was through *The General Magazine of Arts and Sciences, Philosophical, Philological, Mathematical, and Mechanical*: . . ., a comprehensive survey of the arts and sciences, published in monthly sections from 1755-63.[112] The first and most popular section of the *General Magazine*, "The Young Gentleman and Lady's Philosophy"[113] covered topics in natural philosophy by way of a dialogue, and was an excellent way for Martin to publicize his instruments. The conversation was between an educated brother, Cleonicus, who instructed his interested sister, Euphrosine, on various aspects of natural philosophy. Cleonicus demonstrated the principles of natural philosophy, from the solar system to optics and pneumatics, by using experimental apparatus that could be found for sale in Martin's shop.[114] Through the dialogue, Martin could introduce his readers to a multitude of instruments, explain the scientific principles behind them, and instruct the public how to use the apparatus, in an easily read format. *The General Magazine* was a creative way for Martin to market instruments sold at his store. Furthermore, as an author in natural

[112] Millburn, *Benjamin Martin*, 68-79.
[113] After the *General Magazine's* publishing run *The Young Gentleman and Lady's Philosophy*, was republished on its own in 1772.
[114] Millburn, *Benjamin Martin*, 71-73.

philosophy, he must have appeared as a credible source to the average person interested in buying instruments.

For ten years *The General Magazine* provided Martin with a platform to advertise his instruments. However, it was one thing to advertise instruments and another to publish priced catalogues in publications. Instrument-makers had often printed catalogues listing the apparatus that they sold; however, Martin was somewhat of an innovator in that he listed the actual price of instruments. His *The Theory of Comets Illustrated* is an early example of his detailed priced catalogues, and for twenty years he maintained this practice in numerous publications. His competitors, like Adams Sr., also eventually adopted priced catalogues.

The priced catalogues allowed prospective buyers to see what inventory Martin had available for sale and provided him with the opportunity to openly undersell his rivals. This was a specifically important strategy for enticing new customers interested in buying instruments for the first time. By purchasing inexpensive instruments the new buyer could learn the basics of natural philosophy without taking on a major cost. Once familiar and comfortable using the inexpensive instruments, it was the hope of the instrument-maker that the customer would upgrade to more expensive apparatus.[115] Clearly this was an ideal way for Martin to attract customers in the growing philosophical instrument trade. Furthermore, it appears that his priced catalogues may have been a major reason why he obtained a few significant orders from Harvard College after a major fire destroyed much of its instrument collection in 1764.[116] His catalogues may have allowed Professor John Winthrop, who was responsible for replacing the collection

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[115] Biagioli, 25.
[116] Millburn, *Benjamin Martin*, 128-129.

for the College, to identify and price specific apparatus. However, this was not an exclusive order for Martin, as other instrument-makers such as John Dollond, Jeremiah Sisson, James Short, Adams, and Edward Nairne, all sold instruments to Harvard after the fire.[117] Nonetheless, Martin had some unique items to offer, such as his globes, various microscopes, a cometarium, and a special order Grand Orrery.[118] It seems, however, that most of the products that appear on Martin's sales receipt to Harvard College were not specialized instruments, but rather basic sundry items such as pulleys, weights, glass jars and tubes, mirrors, and prisms.[119] This implies that Martin acted more like an instrument retailer, who sold off-the-shelf items at a low price, rather than a sought-after specialist maker. Martin could not, for example, produce high-end telescopes like those of James Short; however, he possessed a large stock of inexpensive items available immediately to prospective customers.[120]

As a non-specialist, Martin did not necessarily have the technical knowledge to develop a difficult instrument or to corner the market for any apparatus. Granted, he was a creative tinkerer, and often altered and improved various instruments; nonetheless, he had never developed a groundbreaking novel item. However, in 1766 he published *The Principles of Pumpwork*, describing an innovative hydraulic pump, which received a patent later that summer.[121] While not an experimental instrument, it is clear that Martin attempted to find a steady source of income with this invention. He tried to sell his pumps to the British Navy but did not win a commission.[122] Moreover, applying for a patent was

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[117] David Wheatland, *The Apparatus of Science at Harvard, 1765-1800*, (Boston: Harvard University by the President and fellows of Harvard College, 1968), 5.
[118] Ibid., 52-55, 60; also, Millburn, *Benjamin Martin*, 131, 133.
[119] Millburn, *Benjamin Martin*, 131-134.
[120] Ibid., 177.
[121] Ibid., 136.
[122] Ibid.

an expensive endeavor and it was equally expensive to litigate interlopers with little precedent in cases of patent infringement.[123] However, in 1763 a precedent had been established when Peter Dollond successfully received royalties from infringements on his father's patent of the achromatic lens.[124] Martin and other instrument-makers must have been more confident with using the patent system for protection, and therefore, thought it may be worthwhile to apply for patents. Unfortunately for Martin, his pump did not catch on and was not a major source of revenue for his business.

Although his patent hydraulic pump was not lucrative, Martin remained in business throughout the 1770s. Martin by then was well into his '60s but continued to revise and improve his stock of instruments, while it appears his son Joshua helped operate the business. It seems that Martin relied on re-edition sales of many of his prior publications to maintain a livelihood, but he also dabbled in clock-making and produced coinage scales when the government applied weight laws to determine legal tender.[125] However, by 1782 Martin's business failed, he was declared bankrupt, and died shortly afterwards from wounds inflicted from a supposed suicide attempt.[126] It is difficult to determine the exact cause of the bankruptcy. Perhaps his son was an inept business man, but surely Martin would have been involved enough to prevent him from running the shop into the ground. Records of his inventory at the time of his bankruptcy indicate that he had an unusually large amount of stock for an instrument-maker at the time, suggesting Martin was by then more of a retailer than a craftsman.[127] It is possible that

[123] Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System, 1660-1800*, (Cambridge: Cambridge University Press, 1988), 60, 76, 78.
[124] Richard Sorrenson, "Dollond & Son's Pursuit of Achromaticity, 1758-1789," *History of Science* 39 (2001): 43.
[125] Millburn, *Benjamin Martin*, 152, 161, 165, 167-168.
[126] Ibid., 172-173.
[127] Ibid., 177.

his inventory was inflated because his instruments were no longer popular at a time of increasing competition. Furthermore, he had republished many of the books he used for advertising; including the very popular *The Young Gentleman and Lady's Philosophy* so it seems the public were still exposed to his instruments. Nonetheless, Martin's market was based on the ebb and flow of fashion, and it could very well be that his business had fallen victim to consumer fads.

It is reasonable to claim that without the prestige and credibility of a fellowship to the Royal Society and specialized technical skill, Martin was limited to the open yet unstable public market.[128] Early in his career he attracted the suspicion of the philosophic community because he broke a major convention that existed within the Royal Society: overtly using natural philosophy for personal profit. Ironically, had Martin veiled his motivations, he might have been admitted as a fellow and could have used the designation to improve his credibility and profitability in the public market place. Furthermore, he would have been better connected with the philosophic elite and may have developed a steady clientele among natural philosophers constantly in need of experimental instruments. Moreover, Martin was a not a skilled craftsman, but acted more like a retailer. James Short, conversely, built the highest quality and most expensive telescopes of the period, and unlike Martin who died bankrupt, left a significant fortune of £20 000 in his will.[129] Short had the benefit of commanding the luxury and professional end of the philosophic instrument market where quality and craftsman reputation moved products. Martin, on the other hand, was limited to the popular public

[128] For an account of fashion and scientific instruments see Jan Golinski, "Barometers of Change: Meteorological Instruments as Machines of Enlightenment," in William Clark, Jan Golinski, and Simon Schaffer, eds. *The Sciences in Enlightened Europe*, (Chicago: University of Chicago Press, 1999), 69-93.
[129] Millburn, *Benjamin* Martin, 151.

instrument market because of his lack of skill and philosophic standing, and had to utilize an aggressive marketing strategy to influence potential buyers in a growing market. Martin's career illustrates a broad view of the nature of the eighteenth-century philosophic instrument market, nourished by the rise of public interest and exposure to experimental natural philosophy. However, it also reveals how a lack of established philosophic credibility and craft skill were a major disadvantage as the market became more competitive. The most successful instrument-makers of the period possessed the skill to develop unique instruments, but also established philosophic standing from within prestigious scientific institutions in order to develop a clientele among natural philosophers, as well as to appear credible in the public market place. The following chapter highlights how John Dollond adhered to the expectations of the philosophic community and developed and maintained his philosophic standing within the Royal Society, while simultaneously translating that credibility into a competitive advantage among the wider public.

CHAPTER THREE

John Dollond

Benjamin Martin's aggressive marketing strategy had garnered him enough business to eke out a living in the philosophic instrument trade. His instruments were aimed at the low end of the market, sold to a public increasingly exposed to natural philosophy. By examining his advertising techniques, we have established an understanding of how philosophic fashion influenced the public market. Furthermore, the dynamic between philosophic credibility and market conditions has been highlighted in my treatment of Martin, as his failed attempt at gaining admission as a fellow at the Royal Society ultimately isolated him from the philosophic elite and limited his success in the fickle public market. Celebrated makers like John Adams Sr. and Jr. provide further perspective on the instrument market as, unlike Martin, they were skilled artisans who developed solid reputations building high-quality navigation and philosophical instruments. Furthermore, the younger Adams displayed an interest in experimental philosophy and developed a level of philosophic legitimacy, as well as valuable business connections, through his publications and membership in the Chapter Coffee House Philosophical Society.

The tension between the philosophic sphere and the market faced by eighteenth-century instrument-makers is further reflected by the protective structure of the English patent system. The Royal Society had been founded on a tradition of scholarly and uninterested openness which was seemingly undermined by monopolies granted by the patent system. Yet many instrument-makers sought patents to protect their inventions in order to earn a living. The following examines how John Dollond avoided the suspicion, and actually gained the trust, of the philosophic community despite patenting his achromatic telescope lens. His son Peter, however, used the patent in a much different way than his father, profited immensely from it, and attracted the ire of both the philosophic and optical communities.

The eighteenth-century English patent system evolved from a previous structure based on Royal privilege, given to individuals as a type of reward for government service or support, into a legal, court-based, framework that placed the onus on the individual patentee to protect their property. Monopolies were originally granted to entice foreign manufacture into England in order to establish commercially beneficial enterprises. A patent application was assessed under the Statute of Monopolies of 1624, which established that a new invention, innovation, or process, could not negatively affect trade or Royal economic interests.[130] Disputes regarding the priority or validity of a patent were arbitrated by six Privy Councillors, who had the authority to revoke patents opposed to the Statute of Monopolies. However, by the mid-eighteenth century, the Privy Council relinquished its authority over patent validity to the common law courts, and individuals were given more agency with regard to what they patented, though at their own risk.[131] By the middle of the eighteenth century the patent system had evolved from a government-controlled instrument of reward into a mechanism for individual protection in competitive markets.

The eighteenth century witnessed a marked increase in patenting activity in nearly all areas of industry. This is generally accounted for because of a general decline in guild authority over trade-secrets. As a result, individual craftsmen saw the patent system as a

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[130] Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System, 1660-1800*, (Cambridge: Cambridge University Press, 1988), 41-42.
[131] Ibid., 58-59.

viable way to protect their livelihoods.[132] Furthermore, a burgeoning culture of consumption had developed, which revealed a growth in general wealth, and therefore, a population more able to take on the expense of patenting.[133] Also, as the patent system was used more frequently, its mechanisms of protection became more widely understood. Related to this increased usage was the development of precedence and case law, which removed some of the uncertainty regarding patent infringement cases. A patentee's ability to gauge a positive outcome of an expensive infringement case was a major incentive to protect his intellectual property.[134] Peter Dollond's successful arbitration of his father's patented achromatic lens was, for example, a major step forward for case law and instilled confidence in other patentees to litigate interlopers.[135]

This increased willingness to patent magnified tensions between the scientific instrument-making community and the philosophic community. The Royal Society, which justified its existence on Baconian principles, had long opposed the idea of secrecy and monopolization of useful knowledge. Like guild secrecy, a patent threatened the free exchange of scientific knowledge because the philosophic instrument-maker could control the availability of the material apparatus necessary for experimentation, replication, and dissemination. Nonetheless, during the first decade of the Royal Society's existence a few of its members, notably Robert Boyle, Robert Hooke, William Petty, and John Evelyn, held that that patenting was preferable to trade-secrecy. The

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[132] Ibid., 87.

[133] Ibid., 146, 149-151, 154-155; also, for a comprehensive look at consumption in the eighteenth-century see Roy Porter, Simon Schaffer, Jim Bennett, and Olivia Brown. Eds, *Science and Profit in 18th-Century London*. (Cambridge: Whipple Museum of the History of Science, 1985).

[134] MacLeod, *Inventing the Industrial Revolution*, 60-64: also Henry Dutton, *The Patent System and Inventive Activity during the Industrial Revolution, 1750-1852.* (Manchester: Manchester University Press, 1984), 69-71.

[135] Benjamin Martin seems to have been emboldened by Peter Dollond's successful litigations. In 1766 he was granted a patent for a hydraulic pump. See Millburn, *Benjamin Martin*, 136.

group proposed the development of a History of Trades, which involved the study and description of numerous craft-trades.[136] Proponents of this programme held that examining trades empirically would improve trade processes and products, as well as reveal new philosophical principles governing craftsmanship. However, the project ultimately failed because many of the Fellows opposed the idea of associating with vulgar mechanics and tradesmen.[137] Moreover, craftsmen felt that revealing their trade-secrets jeopardized their livelihoods as this was a means to control the production in their respective markets. Furthermore, the strength of guilds, before their decline in the eighteenth century, had provided more certain protection for artisans than the patent system.[138] However, the philosophic instrument trade was unique in that it was unregulated by guild control. Into the eighteenth century the patent system was increasingly used as a means of protection for craftsmen's inventions.[139] Despite natural philosophers, like Boyle, who had preferred patenting to outright trade secrecy, patenting philosophic instruments was thought by many natural philosophers as a way to hamper the open dissemination of the practice of philosophy. Open specification, which became mandatory in 1734, was intended to offset some of the secrecy after a patent expired. However, lax specification requirements often led to vague descriptions of novel instruments and revealed very little of their actual construction.[140]

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[136] See Walter E. Houghton, "The History of Trades: its Relation to Seventeenth-Century Thought: As Seen in Bacon, Petty, Evelyn and Boyle," *Journal of the history of Ideas* 2, no.1 (Jan. 1941): 33-60; also Kathleen H. Ochs, "The Royal Society of London's History of Trades Program: An Early Episode in Applied Science," *Notes and Records of the Royal Society of London* 39, no.2 (April, 1985): 129-158.
[137] Houghton, 35, 57; also Ochs, 142-144, 148.
[138] Ochs, 147-148.
[139] Larry Stewart, "Science, Instruments, and Guilds in Early-Modern Britain," *Early Science and Medicine* 10, no. 3 (2005): 394, 396-398.
[140] MacLeod, *Inventing the Industrial Revolution*, 48-54.

The ideal system of reward for invention among the philosophic elite constituted prizes and public recognition, similar to that found in Bacon's *New Atlantis*, where an invention would be publically disclosed for direct and unlimited benefit.[141] The Longitude Act of 1714, which offered a prize to those who could solve the technical problem of finding the longitude at sea, was looked upon by many as an ideal way of gaining credit, providing reward, and sharing utility from an invention. Similarly, by mid-century, the Society of Arts held a policy in which it would not acclaim members who carried a patent, instead admitting only those willing to share their ideas and inventions, often awarding premiums to inventors as an incentive to abstain from patenting.[142] The idealism of these societies, though amicable and well meaning, was criticised for it impracticality and inefficiency. These critics, including the eighteenth-century legal writers W. Kendrick and Edward Goodwin who were informed by laissez-faire economics, felt a government controlled reward system would actually slow inventive activity.[143] They maintained that any such system could not have the resources to reward every useful invention, and as a result, inventors who possessed a significant innovation may not reveal it for lack of reward. Furthermore, a tightly controlled reward system, though effective when solving popular technical issues or planned projects, did not provide incentive for innovative invention for less pressing or fashionable technical problems.[144]

[141] Ibid., 191; also Francis Bacon, *New Atlantis*, (London: 1659), 37-38.
[142] MacLeod, *Inventing the Industrial Revolution*, 194; also, Christine MacLeod, *Heroes of Invention: Technology, Liberalism, and British Identity, 1750-1914*, (Cambridge: Cambridge University Press, 2007), 39.
[143] MacLeod, *Inventing the Industrial Revolution*, 196.
[144] Ibid., 196-197.

Proponents of the patent system, though conceding it was not perfect, felt its benefit lay in placing the onus of risk on the patentee. When patentees developed useful inventions, they would be rewarded sufficiently with a patent and temporary monopoly. In theory, inventions deemed unnecessary or irrelevant to society's needs would not receive a patent through the patent office, and the invention would not sell within the market and the patentee would absorb the financial loss.[145] Again, theoretically, this seemed to be an efficient way of doling out rewards, and the cost-benefit ratio to society might prove favourable. Furthermore, invention would not be limited to any one project or industry, but rather to any industry where innovation could occur. The philosophic community was, however, generally opposed to the limited monopolies awarded to inventors. Proponents felt proper specification would overcome this problem and that after a patent had expired (usually after 14 years), an inventions' construction would be revealed, if it had not already been. Nevertheless, vague specification was not addressed with consistency until the late 1770s when the courts increasingly overturned vaguely or improperly specified patents.[146]

Dollond's Achromatic Lens

Dollond's discovery of the achromatic lens, his publications, and the way he used his patent are instructive for understanding the evolving relationship between philosophic credit and the scientific instrument market. Dollond did not activate his patent's legal potential, but rather, used it as a brand to distinguish his products from competitors. His son Peter, conversely, had no such concerns. Peter exploited a monopoly by enforcing the lens patent, made a significant profit, isolated himself from the Royal Society and

[145] Ibid.
[146] Ibid., 64.

angered the optical instrument-makers. John Dollond had originally won the respect of the philosophic community not only by the weight of the discovery of achromaticity, but also through the empirical method with which he achieved it, and scholarly way he disclosed it. His philosophic reputation and publications in the *Philosophical Transactions* were critical, long after his death, in determining the validity of his patent when it was later disputed on grounds of priority.

John Dollond was of French Huguenot origin, as his father, a silk weaver, came to London after the revocation of the Edict of Nantes.[147] Although he was raised and trained as a silk weaver, he had an inclination for natural philosophy and spent much of his leisure studying mathematics and building and using optical instruments.[148] In 1750 his son Peter established an optical instrument-making business in Spitalfields and in 1752 he was joined by his father at a new location in the Strand.[149] The elder Dollond became interested in a debate concerning the possibility of avoiding chromatic aberration in refracting lenses. Chromatic aberration, essentially a fringe of coloured light that appeared around images viewed in refracting telescopes, seemed to be an unavoidable phenomenon. Newton maintained in his *Opticks* that achromatism was both physically and theoretically impossible to achieve, because refracted white light would always be dispersed into separate colors of the spectrum, and therefore, it was "…the different refrangibility of the rays which hinders the perfection of [refracting] telescopes."[150] However, in 1747, Leonhard Euler, an eminent Swiss mathematician, argued Newton's

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[147] Henry C. King, *The History of the Telescope* (London: Charles Griffin & Co, 1955), 145.
[148] Ibid.
[149] Ibid., 150.
[150] Richard Sorrenson, "Dollond & Son's Pursuit of Achromaticity, 1758-1789," *History of Science* 39 (2001), 32; also Isaac Newton *Opticks*, (London: 1704), 73.

theory was flawed because the human eye, a refracting lens, was achromatic.[151] Euler tried, with little success, to contrive a lens that mimicked the human eye, which he made by joining two curved lenses that contained a water filled center (in order to replicate the aqueous humour of the eye).[152] Despite his failure to produce an achromatic lens, the eye provided Euler with the motivation to reveal his criticism of Newton's theory of achromatism to the Berlin Academy of Sciences, and which he later published in the *Mémoirs* of the French Académie des Sciences in 1749.[153]

Despite such a challenge to England's most famed natural philosopher, the Royal Society did little to respond. James Short, one of London's most respected telescope makers at the time, convinced Dollond to respond to Euler and defend Newton's *Opticks*.[154] It is unclear why Short urged his good friend Dollond to do so. This seems to be a testament to Dollond's ability as a man of science, as Short felt him capable enough to challenge a respected mathematician like Euler; perhaps Dollond had more authority in optics and mathematics than the historical record shows. Short may also have had his own interests at mind as his business was based on reflecting (as opposed to refracting) telescopes at this time, and Euler had challenged his designs. However, this is doubtful as Short strongly encouraged Dollond to publish his discovery of the achromatic lens. Perhaps Short was simply interested in the debate and used his status as a Fellow of the Royal Society to encourage the gifted Dollond to defend Newton. Dollond responded to Euler in 1753, cited Newton's authority and theory of refracted light, and concluded

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[151] Sorrenson, 32; Here Sorrenson explains that we now know the lens of the lens of human eye is in fact not achromatic, our brain removes the chromatic aberration from the refracted images we see. Also, in 1695 David Gregory suggested that the eye was an example of lens that avoided chromatic aberration. I am not sure if Euler's thinking was influenced by Gregory, see King, 144.
[152] King, 145.
[153] Ibid., also, Sorrenson, 33.
[154] James Short, "A Letter from James Short, F.R.S to Peter Daval, Esq.; FRS," *Philosophical Transactions (1683-1775)*, 48 (1753-1754): 287-288.

"…Mr. Euler's theorem is intirely (sic) founded upon a new law of refraction of his own; but that, according to the laws discover'd by experiment, the aberration arising from different refrangibility of light at the object-glass cannot be corrected by any number of refractions whatsoever."[155]

In 1755, the Swedish astronomer and mathematics professor Samuel Klinenstierna, who had read the exchange between Dollond and Euler, wrote to Dollond from his post in Uppsala, stating that Euler was correct to criticize Newton. Klinenstierna claimed, through a geometrical theorem, that Newton's experiment was flawed, and that larger prisms could change the outcome of Newton's famed 'Experiment 8.'[156] He suggested to Dollond that the experiment should be revisited in order to determine if indeed Newton's observations were flawed. Dollond replicated the crucial experiment in 1757 and found by using a water filled prism (the water having similar refractive but different dispersive properties than the prism), he could produce an equal refraction in an object, yet cancel-out the its dispersive effects, and therefore, avoid chromatic aberration.[157] Dollond then discovered, but it is not clear how, that flint and crown glass, like the water prism, had similar refractive, yet different dispersive properties, and could easily be made into telescopic lenses.[158] In 1758 he published his findings in the *Philosophical Transactions*, and created a sensation in both the philosophic and optical community.[159] His philosophical standing had become well established as he challenged one of England's most eminent thinkers, and the achromatic lens allowed for the

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155 John Dollond, "A Letter from Mr. John Dollond to James Short Concerning a Mistake in M. Euler's Theorem for Correcting the Aberrations in the Object-Glass of Refracting Telescopes," *Philosophical Transactions (1683-1775),* 48 (1753-1754): 289-291; quoted from, 291.
156 Sorrenson, 34; also, King, 146.
157 King, 146-147.
158 Sorrenson, 34.
159 See John Dollond, "An Account of some Experiments concerning the Different Refrangibility of Light," *Philosophical Transactions* 1 (1758): 733-743.

development of telescopes that could magnify images with an unprecedented clarity. In 1758 he was duly rewarded by the Royal Society with its highest honour, the Copley Medal, and later in 1761 he was nominated and elected to the Society's Fellowship.[160]

It is with Dollond's discovery that we see an interesting intersection between the expectations of the philosophical community and the needs of the instrument-maker. Dollond was rewarded for his discovery largely because of its significance, but also because he had discovered it through careful experimentation and observation, and openly published his discovery in the prestigious *Philosophical Transactions*. However, Dollond was a craftsman who primarily made his living selling his wares, and he realized his discovery translated into a lucrative commodity. In 1758 he also patented his lens, with the financial support of a fellow optical instrument-maker, Francis Watkins and his enterprising son Peter, no doubt to protect his discovery in a competitive market. Furthermore, in the paper he published in the *Philosophical Transactions*, he described the general principles regarding how the lens functioned; nonetheless, it appears that he was intentionally vague in describing the actual construction of the achromatic lens. This was a measure taken to ensure his priority of discovery, while also concealing from others the knowledge to manufacture the achromats, allowing him to hold the market until the lenses' construction was understood by others.[161] Despite these measures, his manufacturing monopoly did not last long as Benjamin Martin, George Adams, and Henry Pyefinch all developed their own versions within a year of the discovery.[162]

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[160] Sorrenson, 35; for an insightful study of the Royal Society's Copley Medal see, M. Yakup Bektas and Maurice Crosland, "The Copley Medal: The Establishment of a Reward System in the Royal Society, 1731-1839," *Notes and Records of the Royal Society of London* 46, no.1 (Jan., 1992): 43-76.
[161] Sorrenson, 35-36.
[162] King, 150.

Despite philosophical convention, Dollond patented his lens without compromising his standing among the members of the Royal Society and financially benefited from it.

Christine MacLeod has identified two categories of patent use: orthodox and heterodox patenting. Orthodox patenting is characterized by using a patent as a legal mechanism to protect ones' private property, which includes the legal authority to challenge interlopers.[163] Heterodox patenting, however, involves the use of a patent without actually activating its legal potential. Often an inventor who could not afford the significant cost of prosecuting interlopers, or was uncertain about the chance of winning an infringement case, could still use the patent as a symbol of credit or legitimacy in a competitive market - much like branding an original product by separating it from 'generic' replicas.[164] Although costs and legal uncertainty were major deterrents against enforcing a patent, the stigma that a patent-protected monopoly carried within the scientific community, which was committed to the free exchange of knowledge, was often just as undesirable for the inventor. Heterodox patenting practices allowed philosophic instrument-makers to gain a market advantage through branding, while avoiding the ire and suspicion that came with a restrictive patent.

Dollond's achromatic lens moved from a period of heterodox patenting from 1758-1761 to legally enforced orthodox patenting from 1761 until its expiration in 1772. It seems clear that his business-minded son Peter and financier Francis Watkins both understood the financial potential of a patent, and encouraged the elder Dollond to apply for one.[165] It is difficult to gauge the elder Dollond's motivations to patent, as he clearly

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[163] MacLeod, *Inventing the Industrial Revolution*, 88-89.
[164] Ibid., 85; also, Mario Biagioli, "From Print to Patents: Living on Instruments in Early Modern Europe," *History of Science*, 44 (2006), 6.
[165] Sorrenson, 37.

respected the conventions of the philosophic elite and had a genuine interest in natural philosophy. While his motivations may have been conflicted, it appears, given by the evidence of his vague publication in the *Philosophical Transactions*, he may not have opposed patenting to gain a market advantage, although a monopoly was beyond his taste. The fact that Peter legally enforced the patent after his father's death may indicate that John Dollond was opposed to an exclusive monopoly on manufacturing the lens possibly because his moral leanings as a natural philosopher rejected the complete blockage of useful knowledge. As hypocritical as it may seem that John Dollond, a man of science, would patent his lens we must understand the market within which he worked. Like any craftsman, he made a living by selling his products. He did not have the financial freedom of a landed gentleman or even a court connection like a Galileo, who could afford to give telescopes away to illustrious patrons. [166]

Heterodox patenting provided a fair compromise for Dollond. He legally affirmed his priority to the invention with a patent, supplementing the philosophic credit achieved through his publication to the *Philosophical Transactions*. Dollond had it both ways. It appears branding was effective in terms of a market advantage, as rival optician Christopher Steadman complained that Dollond sold achromats "at a much higher rate than that what they have always been sold at by others in the trade."[167] Cleverly, Dollond balanced philosophic standing with his business needs through this protection strategy. Without enforcing the patent in this way, the Dollonds initially avoided incurring the costs and uncertainty that came with litigating interlopers, a risk compounded by the lack

[166] Ibid., 35-36; also regarding Galileo's promotion of his telescopes see, Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy*, (Chicago and London: The University of Chicago Press, 2006).
[167] Steadman quoted in Biagioli, "From Print to Patents," 6; also Sorrenson, 52.

of precedents in the area of patent infringement.[168] John Dollond deftly traversed both the expectations, while selling his instruments for a profit in the larger market. However, his enterprising son, Peter, upset this balance after his father's death by enforcing the patent's legal authority, establishing a manufacturing monopoly of the achromatic lens.

Monopoly, Money, and Peter Dollond

In 1761 John Dollond received a Fellowship to the Royal Society for his contributions to the field of optics. He died later that year having never used his patent as a protective legal instrument. However, Peter, owning a percentage of the patent, made the decision to litigate interlopers in 1763, placing his first claim against his financial partner Francis Watkins. The two men had been involved in a dispute concerning the division of profits from the sale of achromatic telescopes. Unable to reach an agreement, Peter bought out Watkins' partnership and patent rights for £200. Watkins, despite relinquishing his legal right to the patented lens, unsurprisingly continued to produce them, as other lens makers had been doing this since 1759.[169] Peter, perhaps partly motivated by animosity towards Watkins, then sued him for patent infringement, setting off a chain of infringement cases against other optical instrument-makers who were building achromats.[170] His risk and expense was well rewarded as he won his cases against Watkins and seven other opticians, all of whom were ordered to no longer produce achromatic lenses.[171]

In 1764, thirty-five rival instrument-makers, incensed by the monopoly, signed a petition to the Privy Council in the hopes of overturning the court's ruling. The Privy

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[168] MacLeod, *Inventing the Industrial Revolution*, 60-64; also, Dutton, 69-71
[169] Sorrenson, 38.
[170] Ibid, 40.
[171] Ibid.

Council was designed to review cases that posed a threat to legislation under the Statute of Monopolies of 1624, intended to encourage economic improvement.[172] The petitioners claimed Dollond's monopoly was devastating to the optical instrument trade (compounded by declining guild enforcement) because the achromatic lens rendered the reflecting telescope obsolete. Dollond had been handed a monopoly that extended beyond lenses, to the entire telescope-making trade.[173] Nonetheless, the petition was rejected because the Privy Council no longer handled patent disputes, and therefore, the opticians were forced to contest the matter in the law courts.[174] Here they tried first to revoke Dollond's patent by claiming that it was vaguely specified and therefore, upon the expiration of the patent, it would be impossible for others to learn how to make it. Though true, vague specification was already common practice among patentees and rarely enforced, and, the fact that opticians had already learned how to make the lenses regardless of the poor specification, further weakened their argument.[175] The courts paid little attention to the petitioners' concerns regarding specification. However, a more serious issue materialized as they brought forward the claim that Dollond had wrongly been accorded credit for inventing the lens.

The opticians claimed that Chester Moor Hall, a reclusive gentleman lawyer from Essex who dabbled in optical instrument making in his spare time, had invented the achromatic lens much earlier than Dollond. Richard Sorrenson has reconstructed much of the trial proceedings and has updated the historiography surrounding the priority case.[176]

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[172] MacLeod, *Inventing the Industrial Revolution*, 70, 41-42.
[173] Sorrenson, 40.
[174] Ibid., 41, 53; also MacLeod, *Inventing the Industrial Revolution*, 73-74.
[175] Sorrenson., 41.
[176] Ibid.; Sorrenson does not base his account of the trial on Jesse Ramsden's own possibly biased recollection written in 1789. Henry C. King's *History of the Telescope* is problematic because he does not consider that Ramsden may be prejudiced but takes him as absolutely credible.

The opticians maintained Hall had ordered London opticians to make both flint and crown glass lenses in the 1730s and therefore, he had known combining them reduced chromatic aberration. The opticians James Ayscough and William Eastland, who had alleged ties to Hall, had supposedly constructed achromatic lenses by 1752, and the latter had an achromatic telescope on display in his shop in 1753.[177] However, Hall, Ayscough, and Eastland were to be discredited as they could not provide the court with an actual achromatic lens of their own that clearly predated Dollond's. The court ruled in favour of Dollond claiming that even had Hall developed the lens first it ". . . must be considered as nothing; for if a man has ever so useful an invention, and he kept it locked up in his Scrutoire, it was the same thing to the world, as if he had never known it."[178] Even if Hall had invented the achromatic lens, although he had the credibility of an uninterested gentleman, his secretiveness ultimately ruined any chance of proving his priority. Public claim to invention proved critical. Peter Dollond secured his patent largely because his father had an openly documented account of his priority through his publication to the *Philosophical Transactions*. Ironically, John Dollond's philosophic recognition helped cement Peter's monopoly in achromatic lens making.

The historiography surrounding Chester Moor Hall's development of the achromatic lens is slightly cloudy. Henry C. King's comprehensive, yet problematic, account of the trial has been a staple resource on the topic. King based his work on the priority of achromatic lens on Jesse Ramsden's account of the Dollond trial, which was presented to the Royal Society more than thirty years after the fact (a year later he

[177] Ibid., 42.
[178] Quoted in Ibid., 43.

published a similar account in the *Gentleman's Magazine*).[179] The issue here is that Peter Dollond was Ramsden's rival, and therefore, Ramsden cannot be taken as an impartial observer. He may have written his account in order to curry favour with the Royal Society. This occurred at a time when its President, Joseph Banks, and several of its members did not support Ramsden in a dispute with the director of the Ordinance Survey over the delayed manufacture of a theodolite.[180] Sorrenson postulates that Ramsden was trying to reassure the Fellows of Royal Society that he was more than a mere artisan and businessman, but an honest man of science concerned with truth. Interestingly, Ramsden had worked in Dollond's shop in the 1760s and married John Dollond's daughter, and yet, he maintained that Hall, and not his father-in-law, was the first to make the lens.[181] He claimed to the Royal Society that not even family should be an obstacle to what he believed to be the truth.

King, informed by Ramsden, also credits Hall as the inventor of the achromatic lens; and he argues that it was the Hall's silent and humble nature that caused him to lose priority. Essentially, King maintains, in the 1730s Hall had asked James Mann and Edward Scarlett to grind one of the components of the achromatic doublet. However, both men subcontracted the work to the London lens-maker George Bass, who learned that the order was for the same person, and placed the crown and flint lenses together and hereby discovered Hall's achromatic lens.[182] King claims that John Dollond had learned how to make an achromatic lens through Robert Rew in 1755, (though Ramsden

[179] Jesse Ramsden, *Gentleman's Magazine*, 30 September (London: 1790), 890-891.
[180] Sorrenson, 46.
[181] Ibid., 45.
[182] King, 144.

maintained it was in fact George Bass who disclosed to him the construction of the lens) and therefore, had taken credit for Hall's discovery.[183]

It is difficult to know if Hall had invented the achromatic lens before Dollond. However, it seems many of the claims in favour of Hall's priority are strangely suspicious. Ramsden maintained that Hall's silence and complacency was due to the fact that ". . . Mr. Hall was a gentleman of property, and he did not look to any pecuniary advantage from his discovery."[184] Sorrenson argues the opposite, explaining that Hall's secretive nature is unusual as he had no financial interest in the invention, and, as a man of science, he would have had no qualms about sharing his secret.[185] Furthermore, if several members of the optical community, including Bass, Rew, Mann, Ayscough, and Eastland had known about the design of such a revolutionary invention, one would think they would have built and promoted their own. As we saw later with Dollond's achromatic lens, it required rival instrument-makers little time to replicate it. It also appears that Dollond genuinely knew nothing of the lens while communicating to Euler in 1753, or even in 1755 when he was not yet convinced by Klinenstierna that Newton's 'experiment 8' was flawed. It was in 1757 that Dollond tried the experiment using water for its dispersive qualities, suggesting that he was not aware that flint glass was more effective substitute for water even by this time. With this in mind we can, at the very least, assume Hall's (and Ramsden's) contention that Dollond learned that flint and crown glass had achromatic properties in 1755 is problematic. However, it is unclear if Dollond discovered it independently in 1757, or if he had been informed by someone else about how to construct the achromatic lens with flint and crown glass.

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[183] Ibid., 154; also, Sorrenson, 44.
[184] Ramsden, 890.
[185] Sorrenson, 45.

The questions surrounding priority also have an effect on the way Dollond protected the achromatic lens. Maurice Daumas, who has based much of his work on King, argues that John Dollond did not prosecute interlopers in order to avoid a priority dispute that could reveal Hall's claim to the achromatic lens.[186] If this was the case, then the elder Dollond may have been forced to adopt a heterodox patenting strategy not because of any moral engagement with natural philosophy, but rather, to protect his priority to the lucrative invention. As already mentioned, King's (and therefore Daumas's) methodology is flawed in that it relies on a compromised source and cannot be taken uncritically. However, it is important to remember that actual motivations and perceived ones are two different things. Gaining philosophic credibility was often accomplished through rhetorical spin and perceived motivation. If indeed John Dollond avoided using the legal potential of his patent to dodge a devastating priority case, then he was successful. However, in terms of philosophic credibility, the fact that he used his patent as a heterodox form of promotion rather than a monopoly, participated in philosophic culture through his early communications and publications, and seemingly arrived at his discovery through careful empirical observation, Dollond appeared to be acting the part of the ideal man of science. He was rewarded with the Copley medal and gained a Fellowship to the Royal Society for his efforts, and consequently overcame the ideological tensions that separated instrument-maker and natural philosopher, without relinquishing his livelihood selling the materials of science.

Peter Dollond, conversely, antagonized his fellow instrument-makers and isolated himself from philosophic circles by enforcing a monopoly on achromatic lens production.

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[186] Maurice Daumas, *Scientific Instruments in the Seventeenth and Eighteenth Centuries*, (New York: Praeger Publishers, 1972), 155.

We have already seen, through Benjamin Martin, that the Royal Society was suspicious toward instrument-makers who overtly used natural philosophy purely for profit. Peter Dollond's monopoly was a clear violation of the free exchange of scientific material. Later, when Ramsden renewed the priority debate over the achromatic lens in 1789, he hoped that his own pursuit of truth, and status as a newly acclaimed Fellow of the Society (in 1786) would cause the Society to side with him instead of the business-minded Peter Dollond.[187] Peter Dollond was at a significant disadvantage in the dispute as he was not a Fellow of the Society and did not have the same level of access or the philosophical reputation that Ramsden held.[188] However, it seems the Society did not want to enable the renewed debate which contentiously pitted two distinguished Fellows, John Dollond and Ramsden, against one other and could possibly split the membership into hostile factions.[189]

The irony of the priority dispute is that Peter Dollond relied heavily on his father's philosophic legacy in order to maintain his monopoly of the achromatic lens. John Dollond's life is instructive of the value of openness viewed by the scientific elite, and how, through clever marketing, he could strike a balance between the contradictory ethical framework of the natural philosopher and the monetary pressures of the market. Peter Dollond, nonetheless, demonstrates how a monopoly, though profitable, guaranteed he would never have had the same philosophic standing as his father. As John Dollond used a patent to mark his lens as the branded original, the next chapter will examine how

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[187] Anita McConnell, *Jesse Ramsden (1735-1800) London's Leading Scientific Instrument-maker*, (Aldershot: Ashgate, 2007), 72-73.
[188] For Dollond's responds to Ramsden's priority claims see Peter Dollond, *Some Account of the Discovery made by the later Mr. John Dollond FRS which led to the Grand Improvement of Refracting Telescopes. . . With an Attempt to Account for the Mistake in an Experiment by Sir Isaac Newton*, (London: 1789).
[189] Sorrenson, p. 46.

Edward Nairne established himself as one of the Royal Society's most capable electrical instrument-makers, and used his status *and* a patent to sell his 'medico-electrical' machine in a competitive and fashionable market.

CHAPTER FOUR

The previous chapter highlights how John Dollond balanced the expectations of the philosophic elite and the financial realities of the instrument market, combining scholarly participation with delicate marketing. Essentially his patent was used as a way to brand his significant achromatic lens as a distinct original, discovered by the philosophically credible Dollond, in an open market filled with generic imitations. Dollond's marketing technique allowed other instrument-makers to build achromatic lenses without restriction, promoting open production of philosophic instruments. Yet his name and the way he used the patent provided him with a significant market advantage over his rival makers.

Edward Nairne

Edward Nairne had much in common with John Dollond in that he was an instrument-maker of humble origins, yet gained membership in the philosophic community, and translated this status into a lucrative market advantage. Early in his career as an instrument-maker, he established a reputation among natural philosophers for his high quality products. He was specifically noted as one of the best electrical machine builders in the world. His devices were, according to the celebrated lecturer and fellow of the Royal Society, James Ferguson, made ". . . in the greatest perfection by Mr. Nairne."[190] In addition to his craftsmanship, he was also a noted contributor to electrical theory while the subject was rapidly growing in popularity. He worked and corresponded closely with some of the leading natural philosophers of the day, including Joseph Priestley, Henry Cavendish, and Benjamin Franklin**,** and in 1776 he was nominated as a

[190] Ferguson quoted in Paola Bertucci, "A Philosophical Business: Edward Nairne and the Patent Medical Electrical Machine (1782)," *History of Technology* 23, (2001): 43.

fellow to the Royal Society as "well known to the Royal Society for his several Communications and in general for his Knowledge in Experimental Philosophy."[191] His admission to the Society provided him with an ideal venue to advertise his machine as he demonstrated it first hand to the fellows, who had the means to buy and inclination to use them. Furthermore, Nairne's market expanded to foreign buyers as he utilized the international networks within Royal Society, and likewise in the early 1780s as a member of the Chapter Coffee House Society, which contained members prominent within the international instrument trade.

Despite occupying a significant share of the philosophic electrical machine market and earning an international reputation and clientele among philosophic circles, in 1782 Nairne developed and patented a medical electrical machine and marketed it to an even wider spectrum of society. Whereas Dollond had used his patent as a symbol of his priority over the significant philosophical discovery of achromaticity, Nairne used his patent as a way to build his philosophic standing into his machine, and market it as a philosophically credible medical device in a public market filled with quacks and fly-by-night practitioners who occupied the medical fringe.[192] Interestingly, he maintained his reputation among his philosophic coterie marketing it as both a public healing device and as a philosophic instrument, capable of replicating the latest electrical experiments and demonstrating philosophical laws. Nairne could justify his foray into the public marketplace in terms of public health as his machine healed bodies and nourished minds, while conveniently earning his instruments exposure and business profits.

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[191] Ibid.

[192] For a comprehensive study on quack culture and the eighteenth-century medical market see; Roy Porter *Quacks, Fakers, and Charlatans in Medicine*, (Stroud: Tempus, 2003); also, Roy Porter, *Health for Sale: Quackery in England 1660-1850*, (Manchester and New York: Manchester University Press, 1989).

Electricity as Natural Philosophy

Throughout the eighteenth century, both philosophic circles and the wider public developed an interest in electricity. Natural philosophers were hard-pressed to develop theories that could fully explain its often paradoxical characteristics, and its dramatic and mysterious nature added to its appeal as dramatic entertainment. As Joseph Priestley commented, "…the vulgar of every age, sex, and rank were viewing this prodigy of nature and philosophy with wonder and amazement…" and consequently, "…numbers of persons, in almost every country in Europe, got a livelihood by going about and showing it."[193] The wonder and spectacle of electricity made it a valuable commodity to both the itinerant lecturer and the charlatan; both could command large paying audiences fascinated by the spectacle. Yet natural philosophers, even if not completely averse to the show, tirelessly sought to understand the elusive natural principles that governed electricity.

Francis Hauksbee was one of the first natural philosophers to examine electricity and build experimental electrical apparatus in the eighteenth century. By 1705 he regularly performed phosphorescent demonstrations before the fellowship of the Royal Society by agitating mercury within the evacuated bell jar of an air pump.[194] Throughout the course of his bell jar experiments he discovered that he could produce light simply by rubbing a rotating bell jar, and he established that the light was electrical in nature.[195] Despite developing the first frictional electrical machine, Hauksbee's apparatus did not catch on until the 1740s when his experiments were revisited by German natural

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[193] Joseph Priestly, *The History and Present State of Electricity, With Original Experiments*. 5th ed. (London, 1794), 79-80.
[194] W. D. Hackmann, *Electricity from Glass: The History of the Frictional Electrical Machine, 1600-1850*, (Alphen aan den Rijn: Sijthoff and Noordhoff, 1978), 31.
[195] Ibid., 32.

philosophers. Until then electricity was produced by practitioners rubbing glass or amber rods by hand. This limited the scope of investigation because the static electricity they worked with was both weak and unsteady.

Despite the limitations of electrical production, Stephen Gray became the leading experimenter of electrical matters, performing numerous experiments on the transfer of electrical charges. In 1729 Gray discovered that electricity could be transferred through communication and examined how electric charge could be transmitted along rods, threads, and wire, to other objects.[196] He managed to electrify objects through a line of thread that stretched over 250 meters, and developed a very popular demonstration that involved electrifying a suspended boy who attracted various light objects such as feathers and pieces of paper with his hands, and discharged mild sparks by the touch of curious onlookers.[197] In France, Charles Dufay learned of Hauksbee's and Gray's work on electricity in the early-1730s through communication with the then President of the Royal Society, Hans Sloane. Dufay organized the jumbled work of Hauksbee and Gray and attempted to establish some type of theoretical understanding of electrical forces. Significantly, he established that electricity was a consistent property affecting all material bodies, and developed insights into the nature of electric repulsion.[198]

However, Dufay's role as a consolidator of electrical theory may have been more important to the development of electricity than his own theoretical work because he provided other scholars with a number of experiments to replicate, and an up to date body of knowledge to build upon. By the late 1730s and throughout the 1740s the most

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[196] J. L. Heilbron, *Electricity in the 17th and 18th Centuries*, (Berkeley: University of California Press, 1979), 245.
[197] Ibid., 247; also Patricia Fara, *An Entertainment for Angels: Electricity in the Enlightenment*, (Cambridge: Icon, 2003), 43-44.
[198] Heilbron, 250, 252. 255-257.

innovative work in electricity occurred in Germany. The German scholar J. C. Doppelmayr, who studied in England and later taught in Nuremburg, published *Newly Discovered Phaenomena* in 1744, the first German text wholly devoted to electricity.[199] In this comprehensive study he included the work of Haukesbee, Gray, and Dufay, and as a member of both the Royal Society and Berlin Academy, he was aware of the most recent accounts on electricity, including those of Wilhelm Jacob van s'Gravesande and Pieter van Musschenbroek.[200] *Newly Discovered Phaenomena* was important in that it compiled a comprehensive literature review of the field of electricity for a new generation of German natural philosophers. Most importantly Georg Bose was influenced by Doppelmayr, and he built an improved Haukesbee type machine, which allowed him to perform novel, dramatic, and popular electrical demonstrations in the late 1730s and into the '40s, which were quickly replicated throughout Europe.[201] Bose also improved upon Gray's 'suspended boy' demonstration by electrifying the subject with the consistent and more powerful charge supplied by the machine, thus producing more dramatic effects to interested onlookers.[202] Furthermore, he developed some of his own unique demonstrations, geared more for the entertainment of wealthy patrons than demonstrating theory. Some displays involved igniting spirits and gunpowder while others, being nothing more than tactless practical jokes, involved the electrification of cutlery which would discharge a shock to the unsuspecting hand of a hungry dinner guest. Another, involved 'beautifying sparks,' described proudly in his *Tentamina electrica*, in which a person was electrified on an insulated base while wearing a metal

[199] Ibid., 263.
[200] Ibid.
[201] Ibid., 270; also Hackmann, 68.
[202] Heilbron, 265.

crown, resulting in a dramatic and delightful shower of sparks which engulfed the 'beautified' subject.[203]

Bose's imaginative and entertaining approach to electrical demonstration helped it gain popularity throughout Europe. In France, Antoine Nollet who apprenticed with Dufay in the early 1730s and became one of the leading authorities on electricity well into the second half of the eighteenth century, was extremely impressed with Bose's machine and developed one of his own.[204] In England, John T. Desaguliers was one of the most active electrical researchers into the 1730s, and laboured to understand electricity's characteristics in order to find some type of practical application for it.[205] During the 1740s and into the second half of the century Benjamin Wilson and William Watson, rival British electrical theorists, were viewed as the leading philosophers on the subject in England. And by 1746 the recently retired Philadelphian, Benjamin Franklin, began making important observations on atmospheric electricity and the nature of lightning. He published his observations and attracted the attention of the Royal Society, receiving the Copley Medal in 1753 and elected as a fellow in 1756. By the half-way point of the century a group of natural philosophers who could claim to be experts in the subject were making steps in terms of electrical theory, though admittedly, still could not reach a complete theoretical explanation of its properties.

The invention of the condenser, popularly called the Leyden jar, was pivotal to expanding the study of electrical philosophy. In 1745 Ewald von Kleist developed the portable condenser, essentially a small insulated medicine jar filled with water which,

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[203] Ibid., 265-269; also Fara, 47-49.
[204] Hackmann, 114.
[205] Heilbron, 291.

after being electrified by an electrical machine, could hold its charge for several hours.[206] The professor of natural philosophy, Pieter van Musschenbroek, independently developed his own condenser, coined the Leyden jar by Nollet in tribute to the location of its discovery, while attempting to draw electricity from water.[207] The usefulness of a portable source of electric charge was attractive to natural philosophers; however, it was the strength of the Leyden jar discharges that specifically impressed experimenters.[208] Musschenbroek discovered the power of the Leyden jar when he accidently shocked himself, writing to René Antoine de Réamur of the Paris Academy of the experience:

> I would like to tell you about a new but, terrible experiment, which I advise you never to try yourself, nor would I, who have experienced it and survived by the grace of God, do it again for all the kingdom of France…[From the Leyden jar] I tried to draw the snapping sparks that jump from the iron tube to the finger; thereupon my right hand…was struck with such force that my whole body quivered just like someone struck by lightening…the arm and the entire body are affected so terribly I can't describe it. I thought I was done for.[209]

Nollet, undeterred by Musschenbroek's warning, tried the experiment himself and confirmed his own experience of a violent shock. Watson, who introduced the Leyden jar to the Royal Society, recounted his first shock from the condenser stating that it felt "as though my arm were struck off at my shoulder, elbow and wrist, and both my legs, at the knees, and behind the ankles."[210] Upon trying the shock, the professor of natural philosophy at Leyden, Johann Winkler "…found great Convulsions by it in my Body…" and it "…gave me twice a Bleeding at my Nose…" to which he stated he was not commonly inclined. He then performed the experiments on his wife, knocking her off her

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[206] Ibid., 309-310.
[207] Fara, 53.
[208] Heilbron., 312-313.
[209] Musschenbroek quoted in Ibid., 313-314.
[210] Christa Jungnickel and Russell McCormmach, *Cavendish: The Experimental Life*, (Cranbury, N. J.: Bucknell, 1999), 179; Watson quoted in Heilbron, 318.

feet and temporary paralysing her.[211] Soon natural philosophers began studies on how shocks were transmitted though circuits. Nollet in particular performed many famous experiments that involved shocking lines of people, including 180 soldiers at Versailles and 200 Carthusian monks. Watson and some of the fellows of the Royal Society tried to measure the speed of the shock through the chain of people, but concluded that it traveled too quickly to calculate.[212] It was not long until experimenters increased the strength of the shocks by connecting several jars in parallel to form a 'battery,' which had the strength to melt wire and kill animals.[213] Joseph Priestley built one of the first large batteries which consisted of 64 interconnected jars, and by the 1780s some batteries were well over 200 Leyden jars strong.[214]

Although several electrical theories existed, none could completely explain the nature of electricity. Benjamin Franklin claimed that the Leyden jar provided proof of the existence of 'plus' and 'minus' charged electricity within common matter.[215] When the Leyden jar was being literally 'charged up' by an electrical machine, the electricity within the jar was increasingly positive, and a discharging of the jar resulted in the release of the positive electricity to negatively or less positively charged surroundings; upon completion, the charge inside of the jar would reach an equilibrium with the outside. Nollet was opposed to Franklin's view for several reasons. He postulated that glass was permeable to electricity and therefore would leak Franklin's positively charged electricity. Furthermore, Nollet maintained that two different electrical 'fluids' existed

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[211] Fara, 55.
[212] Fara, 56; also Heilbron, 320.
[213] Fara, 56.
[214] On the development of the Leyden jar battery see Hackmann, 99-103.
[215] Heilbron, 328-329; also Jessica Riskin, *Science in the Age of Sensibility: The Sentimental Empiricists of the French Enlightenment*, (Chicago and London: The University of Chicago Press), 86.

and it was the collision of the two fluids that caused a Leyden jar discharge.[216] Moreover, Nollet objected to Franklin's way of thinking, claiming it was philosophically flawed as it was speculative because Franklin focused only on final cause, and did not adhere to a larger mechanistic explanation. For Nollet, Franklin's account of positive and negative electricity was simply arbitrary because it was not applicable to other phenomena. He reasoned against Franklin's equilibrium of electricity that "If I saw an inanimate object move itself toward another, for the sole reason that it lacked what the other could give it, I would believe I had seen a miracle."[217] Despite such disagreements over theory and the principles that governed electricity, natural philosophers did not hesitate to postulate possible practical uses of studying electricity. Two of the most cogent examples of this were the development of the lightning rod used to protect houses from destructive electrical strikes, and the development of a medical application for electricity. These applications will be discussed later in the chapter, but first let us place Edward Nairne within the context of this electrical tradition.

Nairne: Natural Philosopher and Instrument-Maker

Nairne was apprenticed to the London optical instrument-maker Mathew Loft at 20 Cornhill in London in 1741, and eventually took over and expanded his master's business. By 1774 he had taken in a former apprentice, Thomas Blunt, as a joint owner and they built and sold a wide array of instruments, including spectacles, microscopes, telescopes, prisms, and navigational instruments.[218] Nairne made a name for himself

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[216] Riskin, 89.
[217] Ibid., 82-83.
[218] E. G. R. Taylor, *The Mathematical Practitioners of Hanoverian England, 1714-1840*, (Cambridge: Cambridge University Press, 1966), 214, 293; For a list of instruments he made by 1770 see his trade card, printed in both English and French, Edward Nairne, *Edward Nairne Optical, Philosophical, and Mathematical Instrument-maker …* (London: 1770?).

building electrical machines for the increasingly popular study of electrical philosophy. James Ferguson FRS wrote, in his popular *An Introduction to Electricity* published in 1770, that "The electrical machine, mostly now in use…is made in the greatest perfection by Mr. Edward Nairne," and that he had used one of them in his lectures since 1761.[219] In 1773 Nairne developed his "New and Improv'd Electrical Machine" a more powerful version of his previous design which became extremely popular with the leading lights of electrical philosophy.[220] In addition to his reputation for quality and as an innovative craftsman Nairne was also noted as a capable experimenter. Before his nomination to the Royal Society, he was occasionally asked to demonstrate his machine before the fellows – his first appearance being in 1765.[221] He proved that he was more than a craftsman as he published several significant articles on electricity, which displayed some Franklinist influence, and described novel electrical experiments on living animals and plants.[222] Nairne's participation in philosophic culture, by demonstrating and publishing innovative work on the fashionable topic of electricity, was recognized by the fellows of the Royal Society and he was nominated for fellowship in 1776.

After successfully gaining fellowship to the Royal Society he continued his philosophical experiments and he was widely viewed as an expert on matters of electricity. In 1777 he was appointed a member of the Royal Society committee to investigate the controversy over the efficacy of pointed lighting rods in comparison to

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[219] Hackmann, 117; also Bertucci, "A philosophical Business," 43.
[220] Bertucci, "A Philosophical Business," 44, Joseph Priestly, Benjamin Franklin, and Henry Cavendish owned and swore by the Nairne Machine.
[221] Ibid.43, 44.
[222] Ibid., 44-45; Nairne was influenced by Franklin's electrical thinking. His electrical machines were designed to produce negative and positive electricity as postulated by Franklinist theory. Furthermore he was awarded a membership to the American Philosophical Society in 1770, six years before his election to the Royal Society of London. For some of his experiments see Edward Nairne, "Electrical Experiments by Mr. Edward Nairne, of London, Mathematical Instrument-Maker, Made with a Machine of his Own Workmanship, a Description Which is Prefixed," *Philosophical Transaction* 64 (1774): 79-89.

blunt ones – a debate that pitted Franklin against Nollet and Wilson. Not surprisingly he sided with his close associate Franklin in an article published in 1778, stating that pointed conductors were indeed much more effective in conducting electricity.[223] Furthermore, he became a member of the Monday Club, a weekly meeting of fellows at the George and Vulture coffee house, where past Royal Society debates were revisited in detail. It was here that Nairne and the brilliant natural philosopher Henry Cavendish, noted for his researches in chemistry and electricity, became closely linked and developed a working relationship discussing and performing electrical experiments.[224] It seems the connections that Nairne made through philosophic clubbing and engagement most likely provided him with all the business he needed to make a living as an instrument-maker. For example, the Grand Duke of Tuscany had requested Priestley to find him the best electrical machine produced in England. Quite naturally Priestley, a prominent fellow of the Royal Society and expert in electricity, informed the Grand Duke that the best Machines were made by his colleague Nairne.[225] The market for his machines was then established in philosophic circles, or at least the demand among natural philosophers was large enough that he did not have to seek clients from the public market. It seems that his publications, demonstrations, and reputation were enough to keep a solid clientele. This may account for why he did not seek a patent for his unique machine made in 1773, that is, before he was elected a fellow of the Royal Society. He may have realized the connections developed as an active participant of philosophic culture would provide him

[223] Edward Nairne, "Experiments on Electricity, Being an Attempt to Shew the Advantage of Elevated Pointed Conductors…," *Philosophical Transactions* 68 (1778): 823-860; also for an examination of the political nature of the lightning rod debate see, Trent A. Mitchell, "The politics of Experiment in the Eighteenth Century: the Pursuit of Audience and the Manipulation of Consensus in the Debate over Lightning Rods," *Eighteenth-Century Studies* 31, no.3 (1998):307-331.
[224] Jungnickel and McCormmach, 299-300; also Bertucci, "A Philosophical Business," 44.
[225] Bertucci, "A Philosophical Business," 45.

with a lucrative market. Given the context of the Dollond controversy, recently in the courts, a patent may have only antagonized the fellows and jeopardized his chances of gaining philosophic standing. As Martin had likewise revealed, some fellows of the Royal Society were antagonistic to profiting from natural philosophy in the marketplace.

Furthermore, Nairne made important connections through the Chapter Coffee House Society which met briefly throughout the 1780s and discussed various topics on natural philosophy. The Chapter Coffee House's membership was interesting because it contained a strong contingent of both Royal Society fellows and reputable instrument-makers, highlighting the close interaction between instrument-making and the practice of experimental philosophy. It appears that the connections made between Coffee House Society members provided instrument-makers with a venue to promote their wares. One of the members, Jean Hyacinthe de Magellan, who attended the majority of Coffee House meetings, adds a specifically intriguing international business connection within the Coffee house.[226] He was a fellow of the Royal Society, but acted as an international purchasing agent employed by the Spanish and Portuguese Government to procure instruments for their natural philosophers, and later, he acted a an agent for other overseas clients.[227] Interestingly, Magellan nominated George Adams Jr. for membership to the Coffee House Society, and conveniently the two men had been involved at least £3,000 worth of instrument sales between 1776 to1787.[228] Similarly, Magellan was one

[226] For the minutes of the Chapter House Philosophical Society See Trevor Levere and Gerard L'E Turner, *Discussing Chemistry and Steam: The Minutes of a Coffee House Philosophical Society, 1780-1787*, (Oxford: Oxford University Press, 2002); these minutes reveal that Magellan attended a large majority of the meetings and Nairne often demonstrated experiments for the members.
[227] E. G. R Taylor, 210-211; also Bertucci, 43.
[228] John R. Millburn, *Adams of Fleet Street, Instrument-maker's to King George III*, (Aldershot: Ashgate, 2000), 191.

of the fellows who nominated Nairne for his fellowship to the Royal Society in 1776.[229] Although it is not apparent that Nairne and Magellan were involved in any major business dealings together, it is clear Nairne had a close contacts who were interested in the scientific instrument trade, and without a doubt, he had the resources to make lucrative business dealings with them. We see a more clear portrait of Nairne the businessman emerge in 1782 when he developed a medical electrical machine designed specifically for the public market. He employed an interesting marketing strategy which involved using a patent and publishing an instruction manual for the machine in order to attract potential customers into his shop. Furthermore, his public enterprise was justifiable to his colleagues among the philosophic community because he employed a rhetoric maintaining that he was motivated by social good and improvement and, therefore, kept his philosophic standing intact.

The Lucrative Medical Electrical Market

Natural philosophers sought a practical use for electricity beyond the display of parlour tricks, jokes and frivolous entertainments popular among the public and practitioners. The noted natural philosopher, Tiberius Cavallo (FRS), maintained in *A Complete Treatises of Electricity in Theory and Practice* that the two practical applications to come from the study of electricity were the development of the lightning rod and the greater understanding and practice of medical electricity.[230] Throughout the eighteenth-century physiologists drew connections between electricity and life, movement, the nervous system and the brain. In the first half of the century it was widely held that movement and sensation occurred due to type a of nervous fluid or vivifying

[229] Bertucci, "A Philosophical Business," 43.
[230] Fara, 63.

principle which connected the brain to the rest of the body.[231] By the 1740s many investigators, aware of how quickly electricity could move, postulated that electricity could be this vivifying property found within the nervous system.[232] Wilson, for example, held that electricity must be the universal subtle fluid that Newton had claimed was extant in all matter.[233] Furthermore, interest developed in the nature of electricity-producing animals, such as the electric eel and torpedo, which seemingly confirmed suspicions that electricity was fundamentally linked to physiology. Henry Cavendish developed his own artificial electric torpedo with the material assistance and encouragement from Nairne, and determined that indeed electric animals produced electricity very similar to that of Leyden jars.[234] By the 1780s, Luigi Galvani, an Italian physician and experimental anatomist, performed influential experiments on animals that seemed to confirm that electricity was linked to the government of motion. He noticed that a frog he had dissected kicked in time to the pulsations of a nearby electrical machine. He then connected a severed frog's leg to its spinal cord via a metal wire and observed the tightening of the animal's leg muscles. Galvani interpreted this as proof that the nervous systems of living things were electrical by nature.[235] However, by the end of the century, Galvani's rival Alessandro Volta refuted this as proof of the frog actually

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[231] Ibid., 147-148.
[232] Fara, 149.
[233] Paola Bertucci, "The Electrical Body of Knowledge: Medical Electricity and Experimental Philosophy in the Mid-eighteenth Century," in Paola Bertucci and G. Pancaldi (eds), *Electric Bodies, Episodes in the History of Medical Electricity*, (Bologna: 2001), 62.
[234] Fara, 149.; also for a comprehensive account of the growing interest in electric eels and torpedoes see James Delbourgo, *A Most Amazing Scene of Wonders: Electricity and Enlightenment in Early America*, (Cambridge: Harvard University Press, 2006), especially ch. 5.
[235] Fara, 151.

producing electricity, demonstrating that the frog was reacting to electricity found in certain metals.[236]

Beyond these studies, the fact that individuals had been experiencing electrification since the time of Gray's experiments naturally caused audiences to note its effects on their bodies. In the mid-1740, the German professor of medicine and philosophy, Johann Gottlob Krüger, and his understudy, Christian Gottlob Kratzenstein, found that electricity produced involuntary muscle motion and increased the pulse rates of test subjects.[237] Bose supported his countrymens' claims and maintained that the body's blood circulation was accelerated after receiving an electric shock.[238] These results were well received by Italian natural philosophers and medical practitioners, and medical electricity became widely employed as a popular healing practice. Giovanni Poleni and Christian Xavier Wabst followed the work of Bose closely and popularized electrical experimentation throughout Italy. When Poleni heard of the physiological observations made by Bose, Krüger, and Kratzenstein, he was quick to repeat and confirm their results.[239] Luigi Sale was one of the first to administer medical electricity regularly in Italy, and communicated his results and successes to Poleni. Soon after a number of electrical practitioners, of various qualifications, capitalized on the growing medical electrical movement and puffed to the public the efficacy of electricity as a healing agent.

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[236] Ibid., 155; also see Giuliano Pancaldi, *Volta: Science and Culture in the Age of Enlightenment*, (Princeton: Princeton University Press, 2003), 190-196.
[237] Paola Bertucci, "Therapeutic Attractions: Early Applications of Electricity to the Art of Healing," in H. A. Whitaker, C. U. M. Smith, S. Finger (eds). *Brain, Mind and Medicine: Essays in Eighteenth-Century Neuroscience*, (Boton: Springer, 2007), 273.
[238] Ibid.
[239] Ibid., 274.

The rest of Europe experienced an increased presence of medical electricity as itinerant lecturers and practitioners demonstrated the alleged medical benefits of electrification. Numerous accounts of miraculous cures circulated in philosophic and public circles. In England much information on the subject came from news on the continent, and was reproduced by some of the members of the Royal Society including Wilson and Watson. John Reddall organized the first lectures on medical electricity in 1746, and in 1756 Richard Lovett published *Subtle Medium*, the first English book on the topic.[240] John Wesley, a Methodist preacher, and Lovett, a lay-clerk, worked together and promoted the practice of medical electricity because it could be used as an inexpensive way to heal the poor. Using machines made by John Read, a cabinet maker himself healed by medical electricity, Lovett offered free medical treatments in his London Dispensary and published its successes.[241] Even Watson, originally incredulous of the effectiveness of medical electricity, recorded successful treatments. He wrote of a seven-year old girl who was afflicted "…by an universal rigidity of the muscles, reduced to such a state, that her body seemed rather dead than alive…" who was completely healed upon receiving electrical treatments for two months.[242] Furthermore the development of the electrometer in 1765 by the English instrument-maker Timothy Lane, facilitated the spread of medical electricity because it allowed for practitioners to regulate shocks from prime conductors and Leyden jars. The electrometer encouraged the use of softer, less painful, shocks and gentle electrical treatment, more acceptable to prospective medical-electric patients. Furthermore, into the 1770s and '80s electrical machines were being

[240] Ibid., 276.
[241] Ibid.
[242] Tiberius Cavallo, *An Essay on the Theory and Practice of Medical Electricity*, 2nd ed, (London: 1781), 95-96.

purpose built for medical electricity, and instrument-makers developed various types of interchangeable adaptors, designed to apply shocks for specific illnesses and areas of the body.[243]

The early medical electrical market, with its theoretical ambiguity, provided licence for dubious practitioners to take advantage of a desperate and sick public willing to go to any lengths for medical treatment. The academic establishment was often critical of the claims made by many medical electrical practitioners and attempts were made to police them and establish a boundary between legitimate and fraudulent medical practice. Nollet, for example, was one of the leading authorities on the continent, and in 1746 he had tried, unsuccessfully, to cure paralytics with the Leyden jar.[244] He resumed his experiments on paralytics in Paris at the Hôpital des Invalides in 1748 upon hearing of the reputable Swiss physics professor Jean Jallabert's cure of a paralytic man.[245] However, the renewed investigations proved once again unsuccessful and reinforced his scepticism over the medical application of electricity. Yet, since the 1740s, rumours continued to spread across Europe about miraculous medical electrical cures occurring in Italy. As a response to this, Nollet embarked on a three year tour of Italy in 1749, where he exposed electrical quacks and charlatans who promised miracle cures. He discredited, for example, Gianfrancesco Pivati's medical treatment which involved electrifying sealed 'medicated tubes' filled with opium, perfumes, and other healing substances, which allegedly produced a type of medicated vapour breathed in for the benefit of the patient.[246]

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[243] Bertucci, "Therapeutic Attractions," 278.
[244] Heilbron, 353.
[245] Bertucci, "Therapeutic Attractions," 277.
[246] Ibid., 275; also Heilbron, 354 ; and Fara, 91-92.

Despite the scepticism of many leading natural philosophers, others felt that the medical cures were real. Watson, who once felt electricity had no practical use and supported Nollet's tour in Italy, was later convinced it had a medical application upon healing a young girl.[247] Furthermore, by the 1780s, several hospitals in England had formed electrical wards and used electrical machines in therapy. John Birch, a respected surgeon, established a reputable electrical department at St. Thomas Hospital in London and operated it for over twenty years even treating members of the Royal family.[248] Meanwhile, in 1780 James Graham, later tarred as a quack, opened the very popular Temple of Health in London, where he enjoyed over 200 customers daily. In his extravagant healing temple he offered private treatment rooms that were imbued with exotic aromas, music, and ambient electricity said to heal all matters of illness, including sexual disorders, which he puffed could be remedied with a sensual experience in his electrified Celestial Bed.[249] The fact that a Birch and Graham could coexist in such close proximity reflects the fashion for electricity, the difficulty of delineating a distinction between legitimate and quack health providers, and the measures an ill population would take to seek treatment in a time when the state of health care was lacking. Furthermore, this reveals how the open and un-regulated English public medical market allowed practitioners of all sorts to function so long as there was a demand for their services.[250] Similarly, instrument-makers, such as Adams Jr. and Martin, met the market demand for specialized electrical medical machines, realizing that there was money to be made

[247] Watson was the first to communicate the results of Nollet's tour of Italy, see Bertucci, "The Electrical Body," 62.
[248] Fara, 96; also see John Birch, *Considerations on the Efficacy of Electricity, in Removing Female Obstructions*, (London: 1779).
[249] Fara, 86-87, also Bertucci, "Therapeutic Attractions," 281.
[250] This is opposed to the more closely state controlled medical and instrument market in France at this time, see Fara, 97-98.

supplying practitioners. As for Nairne, he saw an opportunity to advertise his philosophic standing in the medical electric market in order to separate himself from competitors, and make a significant profit. He did this without antagonizing his peers among the philosophical elite.

The 'Patent Medical Electrical Machine'

Despite establishing a solid reputation, as well as a significant cliental among philosophic circles, Nairne developed and patented a compact medical electrical machine which he marketed for sale to a broad range of customers. In 1782 he was awarded a patent for ". . . his new invented & most useful improvement in the common Electrical machine. . .," the medical electrical machine.[251] It seems that Nairne wanted to translate his reputation as an electrical instrument-maker into profit in the wildly popular medical electric market of the late eighteenth century. Interestingly, his foray into the public market was not offensive to his philosophical peers because he marketed the machine as both a healing device and a philosophic tool which he maintained would benefit the health and minds of the public.

The fact that Nairne had taken out a patent on his machine is significant in that a patent generally violated the scholarly expectation of openness within philosophic circles. However, Nairne avoided this problem by employing the patent in a heterodox way. There is no evidence that he litigated others who plagiarized his design, and he openly disclosed its construction in a pamphlet describing the machine which was included upon purchase.[252] By doing this Nairne adhered to the expectations of the philosophic elite.

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[251] Nairne's specification can be found at Public Record Office, Chancery Petty Bag Office, IND 1/6941.
[252] Bertucci, "A Philosophical Business," 49; also Edward Nairne, *The Description and Use of Nairne's Patent Electrical Machine; with the Addition of some Philosophical Experiments, and Medical Observations*, 4th edition, (London: 1793), 2-20.

While Dollond had used a patent to seal and brand his philosophic standing and priority within a novel product, Nairne used his as a way to advertise his already established philosophic standing and reputation as an accomplished craftsman. With a patent he transferred his name and legitimacy into a medical machine sold in the unregulated public marketplace. His fellowship to the Royal Society, and experience as an active experimentalist among the leading philosophers of the day, combined with a patent, allowed him to establish his machine as an authentic healing device in the public market rife with quacks.

The publication of *A Description and Use of Nairne's Patent Electrical Machine* employs rhetoric that focuses on the philosophic grounding of both Nairne and his machine. He soberly admits that electricity's "… application to the cure of disorders has been exceedingly magnified by some writers…" and "…those who are fond of the marvellous have led many patients into the expectation, that their disorders will vanish as it were by enchantment."[253] However, he maintains that "… electricity is almost a specific in some disorders, and deserves to be held in the highest estimation for its efficacy in many others."[254] Moreover, he reassures his readers, by appealing to his own philosophic authority and connections within the philosophic community, that the successes described in his tract, "…contains not a single assertion which has not been confirmed either by the author's own experience, or the testimony of a numerous acquaintance of ingenious and worthy gentleman."[255] He cites that he has published several papers on electricity in the *Philosophical Transactions* and that he has informed

[253] Nairne, *A Description and Use*, 56, 69.
[254] Ibid., 56.
[255] Ibid.

the claims found in *A Description and Use* from other fellows and notable authorities including Cavallo, Birch, Lovett and Wesley.[256]

By reassuring his readers that he was a published member of the philosophic community, and used up-to-date sources from experts in the field of medical electricity, Nairne injected legitimacy into his patented machine. Importantly, he also marketed the machine as "constructed for medical Purposes," but also "EQUALLY APPLICABLE TO PHILOSOPHIC USES," and provided a list of electrical experiments and theoretical explanations of the natural principles found behind them.[257] Furthermore, Nairne's machine could produce both positive and negative electricity as theorized by Franklin, and therefore, was perceived as being up-to-date in electrical theory by natural philosophers and beginners alike.[258] By focusing on the philosophical capabilities of the machine, Nairne could convince beginners and experts that this machine was an authentic, philosophically-grounded machine. Moreover he could justify its sale within the wide public to his scientific peers because it was an instrument capable of disseminating sound natural philosophy.

By establishing the philosophic credibility of the machine and its maker, it was much more likely that the public would buy it as a genuine medical instrument as opposed to competitors in the market who did not possess the same high credentials. Nairne also promoted his machine as a self-healing device by which "…any person may try the Effects of the Electricity on themselves without the assistance or Knowledge of

[256] Ibid., 70-71.
[257] Nairne quoted in Bertucci, "A Philosophical Business," 51, also see Nairne, *A Description and Use*, ch 5, for his section on "Philosophical Experiments and Observations."
[258] Nairne, *Description and Use*, 53-54.

any other…"[259] This was an attractive prospect to the public because self-application would potentially eliminate the costs of acquiring a medical practitioner for treatment. Furthermore, it provided amateurs with an opportunity to start their own medical-electrical enterprises, by using an authentic Nairne machine. Self-application and amateur use of the machine was facilitated by Nairne's insistence on its safety as "…the strongest shocks requisite for any disorder may be given…without any danger to the person requiring them."[260] Interestingly, he could justify the sale of his machine to his philosophical counterparts because it was sold for the public good as healing device widely used by all levels of society. This thinking was similar to John Wesley in the 1750s, motivated by Methodist piety and philanthropy, who had viewed medical electricity as a cheap and plentiful way to heal the poor.[261]

Various traditions of the value of social good existed among the ranks of natural philosophers. In the 1660s the Royal Society had justified its existence to the Restoration Monarchy in terms of utility, in that it provided a sober revelation of God's natural laws, would overcome socially destabilizing public superstition, and promised Baconian improvements in industry, and shipping. Newton's later *Principia* asserted that the universe was governed by rational and universal laws designed by God. Interestingly, some, like Wesley, viewed the healing powers of electricity to be a divine gift from God, while others, like John Freke, felt it was a sacrilegious to meddle with such a powerful force.[262] Others, like Priestley, determined that natural philosophy was an exercise of

[259] Public Record Office, C66/3791/16, (London: 1782).
[260] Nairne, *A Description and Use*, 66.
[261] Paola, Bertucci, "Revealing Sparks: John Wesley and the Religious Utility of Electrical Healing," *British Society for the History of Science* 39, no. 3 (September, 2006): 347-348.
[262] On Freke's religious opposition to using electricity see Simon Schaffer, "The Consuming Flame: Elecrical Showmen and Tory Mystics in the World of Goods," in *Consumption and the World of Goods*, John Brewer and Roy Porter, eds. (London: Routledge, 1993), 489-526.

reason which would undoubtedly result in progress and improvement, and would free humanity from restrictive ignorance and promote improvement and progress at all levels of society.[263] In medical matters, the advancement of medicine and access to health care to all levels of society demonstrated the progressive power of rationality, and affirmed that a healthy society was a rational and productive one.[264] In any case, natural philosophy sought to rationalize the laws of nature, divine or secular, and for the benefit of society, either out of charity, protestant piety, or the enlightenment march of progress. Nairne's machine encompassed the idea of improvement and benefit for the public good by providing a machine, founded on philosophic principles, which could heal and instruct society. For natural philosophers this demonstrated the triumph of rationality, and translated into improvement in the real world.

One could postulate that Nairne entered the medical electrical machine market simply to provide a philosophically up-to-date machine to a public desperate for relief. However, it must be emphasised that his motives are easily concealed because he was a member of the philosophic sphere and employed its rhetoric. In reality, just like Martin, Adams, and Dollond, Nairne made his living selling philosophical instruments and was aware of market potential. Bertucci sums up the cleverness of marketing the machine as both a medical and philosophic instrument, noting that it "was precisely this chameleon-like character of his invention that Nairne exploited in addressing the composite market of amateur electricians, professional and self-trained healers and electrical philosophers."[265] Indeed he was able to extend his influence into the wider public market

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[263] Bertucci, "Revealing Sparks," 361.
[264] Roy Porter, *Doctor of Society: Thomas Beddoes and the Sick Trade in Late-Enlightenment England*, (London: Routledge1992), 39, 58-59.
[265] Bertucci, "A Philosophical Business," 52.

by promoting its user flexibility. Furthermore, it is clear that Nairne was sensitive to market demands and opportunity within the scientific instrument trade early in his career. For example, in 1764, when 35 instrument-makers petitioned against Peter Dollond's patent on the achromatic lens, Nairne did not sign, and chose rather to pay a royalty on the achromatic lenses he made.[266] This may be an indication that he understood the potential benefits of using a patent in his business.

The heterodox way he used his patent, as a container of his FRS and reputation as a skilled craftsmen, demonstrates his marketing savvy and flexibility. He appeased his philosophical counterparts by not restricting the production of his unique machines, yet he distinguished himself from his competitors as a credible provider of a medical machines.[267] Furthermore, exposing the public to his machine, and instructing them to use it with *A Description and Use*, was a way to expand public interest in Natural Philosophy and increase the number of potential customers. As a result, the curious amateur natural philosopher could be influenced to purchase other philosophic instruments at his shop. In *A Description and Use* Nairne informs buyers that "if an accident should happen to any part of the electrical machine it can be replaced . . ." at his shop, "…without sending the other parts."[268] Further evidence that he was concerned with increasing his clientele, is demonstrated in the catalogue appended to end of *A Description and Use,* which included a list of the instruments, from optical, navigational, to mathematical, for sale in his shop. It is clear that he hoped to inform his readers, from a wide social spectrum, that he sold a variety of instruments for all tastes and interests.

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[266] Ibid., 48.
[267] Ibid., 53-54.
[268] Nairne, *A Description and Use,* 19.

It should be noted that I do not intend to portray Nairne as only motivated by profit. Clearly his participation within the philosophic community was driven by a curiosity and interest in natural philosophy. However, an examination of his career reveals that as an instrument-maker he was sensitive to the realities of the market. Yet as a man of science, he was aware of the expectations within the philosophic sphere. His marketing strategy was shaped by the rules of conduct found among the philosophic elite and yet he still satisfied his business needs. By looking at the way he gained membership within philosophic circles through publication and experimental engagement, and later by heterodox patenting and the rhetoric employed within *A Description and Use*, one can clearly see that the instrument-maker was still bound by the gentlemanly philosophic expectations founded in the 1660s

CONCLUSION

Philosophy and Profit

In a recent issue of *Isis,* a focus section on "Historicizing Popular Science," examines the historiography of the study of popular science. The major issue found among the contributors involved the conceptual limitations of developing an artificial dichotomy between the public as consumers of either vulgar scientific knowledge or valid knowledge disseminated from experts knowledge consumers. The complexities and nuances found between the production and consumption of natural knowledge are lost if one only examines the strict dichotomy. What the authors propose is an adherence to James Secord's idea of 'knowledge in transit,' which examines "… the processes, actors and ideas that have aimed at allowing parts of society to participate in knowledge (while excluding others) – without assuming that these processes led necessarily to the development of seemingly distinct public spheres, as opposed to seemingly 'private' ones."[269] Two of the contributors, Jonathan R. Topham and Andreas W. Daum, wish to completely remove the distinction between expert and popular public science as it restricts the degree to which the historian of science comprehends the complexities of how the public was exposed to natural philosophy.[270]

Topham and Daum's insistence on examining the actors, dynamic processes, and interactions between individuals has much merit in that it does capture the ebb and flow of how natural knowledge was consumed by the public. However, to remove the boundary between what was viewed as expert knowledge versus non-expert knowledge in the public sphere also removes an important impetus in the natural knowledge market

[269] Andreas W. Daum, "Varieties of Popular Science and the transformation of Public Knowledge," *Isis* 100 (2009): 329.
[270] See ibid., 319-332; also, Jonathan R. Topham, "Introduction," *Isis* 100 (2009): 310-318.

– the demand for seemingly legitimate knowledge. A third contributor to the focus section, Ralph O'Connor, feels that the delineation between 'popular' and 'expert' science, though restrictive, are necessary because "… these categories represent in shorthand the phenomena about to be analyzed, defamiliarized, made richer."[271] Essentially defining expert and popular boundaries situates the environment that natural knowledge was consumed and provides a framework within which the interactions between the two spheres can be explored, specifically by examining actors such as instrument-makers, who were active in both worlds. The merit of O'Conner is that he provides structure to account for how expert knowledge was a sought-after commodity in the public market. Topham and Daum remove expertise as a powerful market force, and assume that the difference between vulgar and expert knowledge was not discernable by public consumers.

My project maintains that, by examining the philosophic instrument trade, the delineation between an expert scientific elite and a vulgar public market provides a necessary framework for understanding how the eighteenth-century knowledge market functioned. Topham and Daum's method ignores that fact that projectors and charlatans were a real concern among the public and the members of the Royal Society.[272] They overlook the common practice of instrument-makers and itinerant lectures seeking fellowships to recognized scientific institutions in order to gain philosophic standing as a way to separate themselves from rivals in the public market.[273] Moreover, they fail to

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271 Ralph O'Connor, "Reflections on Popular Science in Britain: Genres, Categories, and Historians," *Isis* 100 (2009): 345.
272 Larry Stewart, *The Rise of Public Science: Rhetoric, Technology and natural Philosophy in Newtonian Britain, 1660-1750*, (Cambridge: Cambridge University Press, 1992), 15-16, 21-23.
273 Benjamin Martin, for example, overtly wanted a fellowship to the Royal Society in order to attract larger audiences to his public lectures on natural philosophy, see John R. Millburn, *Benjamin Martin – Author, Instrument-Maker, and 'Country Showman'*, (Leyden: Noordhoff International Publishing,1976), 35-38.

recognize that a patented philosophic instrument was a market advantage, not because of its legal authority (most instrument-makers did not litigate interlopers) but because it represented philosophic expertise that separated its maker from others in a competitive market. The interaction between the Newtonian popularizer and the merchant out to improve his business, and the curious amateur shopping for instruments to replicate an experiment that he paid to see, clearly demonstrates that philosophic credibility was sought at both the supply and demand sides of the market.

Although this thesis is designed to refute Topham and Daum's dismissal of expert and popular categories, it does agree with the contention that examining the actors, their motivations, and interactions is essential to understanding the market place for natural knowledge. By looking at philosophic instrument-makers, agents who permeated both boundaries of the philosophic elite and public sphere, it is possible to understand how the two realms interact. The methodology of this project employs an examination of how instrument-makers tried to meet the expectations of the philosophic elites and market demand through their marketing and advertising strategies. By doing this the role of philosophic credibility in the philosophic instrument market is exposed and light is shed on how it became available to the eighteenth-century public. Furthermore, the constructivist assumption that natural knowledge is influenced by external and human actions is also revealed by the instrument-makers activities. Instrument-makers reacted to public demand as exemplified by Edward Nairne's medical electrical machine. These makers also directed philosophic fashion through clever marketing.[274] Benjamin Martin published popular books and pamphlets which instructed potential buyers on how to use

[274] Paola Bertucci, "A Philosophical Business: Edward Nairne and the Patent Medical Electrical Machine (1782)," *History of Technology* 23, (2001): 41-58.

specific instruments found in his shop. Furthermore, as John Dollond reveals, patents were carefully used in a way so as not to antagonize the expectations of the philosophic elite but still capable of achieving the market needs of the instrument-maker. These actions reveal how instrument-makers were influenced by the philosophic elite and found ways to use philosophic credit to direct the consumption of natural philosophy in the public sphere.

This project is significant because it reveals the antecedents of the contemporary relationship between scientific authority and the monetary pressures of the marketplace. Interestingly, by the nineteenth-century the scientist's rhetoric changed somewhat as a focus on the technological spinoffs of natural philosophy had been justified in the context of the rapidly industrializing British landscape. The inventor was no longer painted as a projector, but rather, revered as a champion of British economic prowess. James Watt, provides the perfect example of the glorification of natural philosophy and industry. In 1824 he was honoured posthumously at Westminster by Prime Minister Liverpool, members of cabinet, and the leading lights of the Royal Society for his innovative steam engine.[275] Natural philosophy informed discoveries that were viewed by scientists and the public as beneficial to society. Edward Jenner's smallpox vaccine eliminated a devastating scourge, and Richard Arkwright's textile machinery and Watt and Matthew Boulton's steam power made Britain the world's economic powerhouse.[276] Furthermore, in the nineteenth-century instrument-making workshops grew into high production firms which had in-house workshops with the financial capacity to subcontract to smaller instrument-making businesses, while producing both philosophic and industrial

[275] Christine MacLeod, *Heroes of Invention: Technology, Liberalism, and British Identity, 1750-1914*, (Cambridge: Cambridge University Press, 2007), 60, 91.
[276] Ibid., 60, 65, 72.

instruments.[277] It is here that we see a transformation of credibility. Philosophy for profit was no longer a negative concept, but rather a union glorified as industrial and social progress.

In the twentieth and twenty-first centuries science has become lucrative business, and universities have increasingly focused on developing applied science programs that promise profitable technological outcomes at the expense of purely theoretical endeavors. However, the rhetoric employed today in the high-tech instrument industry is very similar to that of the eighteenth century. Particle accelerators are built on the promise of their practical and theoretical potential and medical isotope reactors are justified because of their diagnostic capabilities. Furthermore, the marketing strategies employed by contemporary university technology transfer units share much with the instrument-makers of eighteenth-century London. While today patents are exercised in their legal sense, and less like brands, they also represent the expertise of the scientific practitioner. The highly-educated scientist, who possesses specialized knowledge, still commands a great deal of authority from non-scientific groups. This authority is imperative for intermediaries who find profitable applications in the scientists' work and attractively package it for the consumer, desiring a legitimate and quality product.[278] By looking at where science was first disseminated to the public as a commodity - eighteenth-century England - one can reflect upon the way science has been shaped into its current highly commercialized form.

[277] A. D. Morrison-Low, *Making Scientific Instruments in the Industrial Revolution*, (Aldershot: Ashgate, 2007), 166-167.
[278] For a comprehensive study on modern technology transfer see, Phyllis L. Speser, *The Art and Science of Technology Transfer*, (New Jersey: Wiley, 2006).

This study reveals that scientific knowledge was disseminated into the early-modern public sphere according to the moral expectations of the philosophic elite and the monetary push of the public market place. It is during the eighteenth century, when scientific knowledge was first commodified and consumed in the public market place, where we see the roots of the contemporary relationship between science and profit. One only has to view the current relationship between university laboratories and private investment, the immense pharmaceutical industry, the growth in the area of intellectual property law, to realize that scientific knowledge still holds a prestigious place in society based on its practical potential. Clearly the contemporary public faith in science is not unlike that of the eighteenth-century public examined in this thesis. Yet it is imperative to perceive science, as I have, as a human endeavor directed by human motivations, rather than one that progresses forward toward ever-increasing social benefit. By doing this, contemporary science can be viewed as an accessory to corporate ambition, and with this realization perhaps it can be given the opportunity to take on a more meaningful status free from the call of the market.

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