A RHETORICAL ANALYSIS OF SIR ISAAC NEWTON'S *PRINCIPIA*

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DEDICATION

Nature and Nature's Laws lay hid in Night:

God said, "Let Newton be!" and all was light.

~ Alexander Pope

Dedicated to all the wonderful eighteenth-century Enlightenment thinkers and philosophers!

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ABSTRACT

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In this thesis, I analyze Isaac Newton's *Philosophiae Naturalis Principia Mathematica* in the framework of Aristotle's theories of rhetoric. Despite the long-held view that science only deals with brute facts and does not require rhetoric, we learn that science has its own special topics. This study highlights the rhetorical situation of the *Principia* and Newton's rhetorical strategies, emphasizing the belief that scientific facts and theories are also rhetorical constructions. This analysis shows that the credibility of the author and the text, the emotional debates before and after the publication of the text, the construction of logical arguments, and the presentation style makes the book the epitome of scientific writing. Through this analysis, I discover the significance of rhetoric science and how it helps us understand science as a subject and how it can be used for the benefit of society.

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CHAPTER I

INTRODUCTION

Isaac Newton's *Philosophiae Naturalis Principia Mathematica* was first published in 1687. In this book, Newton argues that he has discovered the laws and theories that explain natural phenomena, including orbital motions and tides of the sea. He also argues for his way of doing natural philosophy. Newton was the first person to postulate the theory of universal gravitation, in which he claimed that the celestial sphere and the terrestrial sphere were governed by the same laws. His laws of motion provided theoretical support to Kepler's heliocentric model of our solar system and laid the foundation of classical mechanics. To support his laws of motion for celestial objects, Newton provides arguments from geometrical formulations and terrestrial experiments in the *Principia*.

The publication of this book and its subsequent popularization by Newton's followers established Newton's theories, which were considered the ultimate laws of nature for about two hundred years, and made a case for empirical science in which experiments and observations are used to formulate theories. To find out how the *Principia* became such an influential text, I analyzed the text by studying its rhetorical situation and persuasive strategies. This analysis helps us understand science as a subject and as a part of our intellectual heritage. I also looked for answers to questions, such as how the relationship between science and rhetoric has evolved over the years, how the rhetoric of science is different from Aristotelian rhetoric, and how effective it has been in our society.

This analysis is based on the English translation of the third edition of the *Principia* by Andrew Motte, published two years after Newton's death in 1729, and relies on various modern commentaries on the different editions of the *Principia*. Newton wrote the *Principia* in Latin, and it was published in three editions during his lifetime. Out of these three editions, only the third edition has been translated in English. In spite of being a primary source, since the book I read is a translated version, some subtleties and nuances of the language might have been lost in translation. It is not possible to discern the original diction, tone, and phrasing from a translated text. For example, Newton's phrase, "*hypotheses non fingo,*" in the General Scholium of the second and the third edition can be translated as "I frame no hypotheses," or "I feign no hypotheses," or "I contrive no hypotheses;" each of these translations has slightly different connotation.

Since the first and the second editions are available only in Latin, I retrieved the information regarding the changes that Newton made in the later editions from secondary sources. Some of the changes that Newton made in response to his critics strengthened his arguments, and now shed light on his rhetorical strategies. Thus, I have benefited from the works of Newtonian scholars, including I. Bernard Cohen, Richard S. Westfall, George Smith, and Andrew Janiak. These authors provide knowledge and information on the text of the *Principia* as well as on various aspects of Newton's life, including his education, his philosophical outlook, and his disputes with other philosophers, all of which have been helpful in understanding the rhetorical situation of the *Principia.*

Besides studying the text of the *Principia* and its commentaries, I also studied the history of astronomy, the history of rhetoric, and the current scholarship on the rhetoric of science.

Since the *Principia* mostly deals with astronomy, it is pertinent to learn Newton's knowledge of the history of astronomy. Newton used and synthesized knowledge from all available sources—from the Ancients to the Moderns—to form his arguments. Newton would have been well aware of astronomical theories of his predecessors since ancient times. Ancient Greek philosophers/astronomers, such as Aristarchus (310-230 BCE) and Hipparchus (190-120 BCE), made surprisingly accurate discoveries for their time, regarding the Earth and the heavens, but their heliocentric insights did not gain acceptance for centuries. Aristotle and Ptolemy's geocentric model, on the other hand, became the most trusted explanation of the universe for over a thousand years. Ptolemy's treatise *Almagest* was lost to the West until the Middle Ages, and when it was discovered during the Renaissance, its geocentric model was adopted and enforced by the Church. When Copernicus wrote about his heliocentric model in 1543, it was poorly received and was mocked by the other philosophers although his discoveries later proved to be a precursor to the development of astronomy. Another distinguished astronomer was Tycho Brahe (1546-1601), who made extensive observations and tried to fit them in his geo-heliocentric model (Forbes, Chapter 5). During the first half of the seventeenth century, Galileo, Kepler, and Descartes presented their own empirical proofs and theories of physical mechanism to support the Copernican model over the Tychonic model of orbital motions. Galileo invented a telescope and provided evidence for his heliocentric model.

Kepler, who had worked as Brahe's assistant, presented his findings in his book, *Astronomia Nova* (1609). Newton was an inheritor of all this knowledge, and his theories specifically supported Kepler's laws.

Although Newton's knowledge of astronomy and mathematics made him an authority in the field of natural philosophy, his theories were accepted only after he presented long mathematical and experimental arguments in the *Principia*. Newton followed Kepler's theory even though Kepler's findings were one among the other six or seven theories that could explain orbital motions to an approximation (Smith). Newton formulated the laws of motion and the theory of universal gravitation by synthesizing Kepler's and Galileo's theories with his mathematical knowledge. Since Newton's findings did not fit in the scientific paradigm of his time, which was Descartes's mechanistic philosophy, Newton required strong rhetorical appeals to persuade his contemporaries.

Another reason Newton required rhetoric to persuade his contemporaries was that his theories could not explain many phenomena. For example, he was unable to explain exact orbital motions, such as the precession of the perihelion of Mercury and the precession of the Moon's orbital, and could not provide the cause of gravitational attraction. But Newton managed to convince many of his contemporaries by making them believe that future investigations and discoveries would solve the inadequacies. After presenting his arguments in the first edition, Newton addressed the objections of his rivals by strengthening his arguments in the second and the third edition of the *Principia*. In the second edition, he attributed the gravitational attraction to God's working.

Although, initially, the theory of gravitation was under dispute, George Smith writes that "[b]y the 1790s Newton's theory of gravity had become established among those engaged in research in orbital mechanics and physical geodesy, leading to the *Principia* becoming the exemplar of science at its most successful" (1). Thus, following Newton's own arguments, the successful persuasion by his successors made his critics forget their objection regarding the cause of gravitational attraction.

Later, the development of new technologies helped improve the accuracy of telescopic observation and time measurement, and scientists realized that besides the inadequacy in predicting orbital motions, Newton's laws were also inadequate for explaining the mechanics on a quantum level and on a large scale involving the speed of light. This was because Newton was solving problems in the framework of a rectangular coordinate system, which is based on the three-dimensional geometrical space as opposed to the curved space proposed by Einstein. Despite the advances in the field of physics, Newton's laws are still used to solve problems on a smaller scale, where only approximations are required. To find out how Newton constructed his laws and persuaded his contemporaries, we analyze the *Principia* for Newton's use of rhetoric.

Over the years, there have been many changes in the field of natural philosophy or science, but the basics of rhetoric have remained the same, although rhetoric has been used for different purposes in different ways during different periods in history. Since Aristotle's *Rhetoric* (400 BCE) has been a foundational text in the field of rhetoric, I have used it as the main tool to analyze Newton's text. Aristotle defines and categorizes rhetoric in his treatise, *Rhetoric*. He defines rhetoric as the ability to discover all the available means of persuasion in each case. He categorizes these means of persuasion, also called proofs or *pisteis*, into two types—inartistic and artistic. The inartistic proofs are the preexisting ones, and the artistic proofs have to be invented by a speaker. The artistic proofs are appeals to *ethos, pathos,* and *logos.* Where *ethos* is related to the character of a speaker, *pathos* is the quality to evoke emotions in the listeners, and *logos* refers to the logical arguments. Aristotle further stresses that not only should an orator use all available means, but he should also have practical wisdom (*phronesis*), virtue (*arete*), and goodwill (*eunoia*).

In subsequent centuries, Aristotle's work inspired many thinkers and rhetoricians, and was popularized by *Rhetorica ad Herennium,* Cicero's *De Inventione*, and by Quintilian's *Institutio Oratoria.* These books popularized the five canons of rhetoric, which are invention, arrangement, style, memory, and delivery. The five canons served as an outline for creating rhetorical speeches. During the Middle Ages, the Scholastic tradition of syllogistic disputation was at its heights, and there was extra stress on style, especially on the figures of speech. Peter Ramus went against the trend and proposed that only style and delivery belonged to the art of rhetoric. Ramus's treatises influenced the curriculums of European universities, which gave way to bare logic by sidelining rhetoric and practical reasoning. Thus, the separation of rhetoric from science was spearheaded by Ramus who "saw tropes and figures as the means to provoke emotional reactions in the reader… preferring a plain style, a preference that would be later shared by the Puritans and by exponents of the New Science." Although Ramus's logic is considered a precursor to the New Science, seventeenth-century philosopher, Francis Bacon, blamed both

Scholasticism and Ramism for the slow development of philosophy (Rebhorn 261). Bacon harbingered a new way of philosophy that was practiced using observations, experimentations, and inductive reasoning. Bacon's method was the benchmark of philosophical inquiry in Newton's days.

The distrust and denigration of rhetoric continued in the seventeenth century, which is evident from the writings of Thomas Sprat, who was commissioned to write the history of the Royal Society in its formative years. Sprat authored *The History of the Royal Society of London for the Improving of Natural Knowledge* (1667 CE) in which he advocated the use of a plain style, asking the natural philosophers to return "back to the primitive purity" (113). Sprat's work helps us understand the rhetorical traditions of the seventeenth century, which might have influenced Newton's philosophy and his writing style. During Newton's days and until much later, the development of science was considered a product of rational thinking, in which rhetoric had no place, because science was supposed to deal with the brute facts of nature while rhetoric was synonymous with flowery language that mostly dealt with probabilities. Even though rhetoric was studied in universities, in the subsequent centuries, it was distinctly kept apart from science due to the belief that science did not require persuasion.

However, in the late twentieth century, some rhetoricians and scholars turned their attention to the rhetoric of scientific texts and communications. In an anthology, titled *Landmark Essays of Rhetoric of Science,* editor Randy Allen Harris attributes this interest to the publication of Thomas Samuel Kuhn's *Structure of Scientific Revolutions* (xiii). Kuhn stressed that the development of science depends on persuasion (203). He also claimed that rhetoric is not only used to persuade others, but it is also employed as a tool for generating and inventing scientific knowledge. Kuhn's arguments highlight the historical fact that in the past, scientific theories, despite acquiring the status of scientific laws and facts, have been repeatedly replaced whenever they fell short in explaining new discoveries, which shows that they were rhetorical constructions. For example, the belief that the Earth was still and all the planets, stars and the Sun revolved around the Earth was subsequently replaced by Copernicus's heliocentric theory, and then modified by Kepler and Newton, which in turn has been replaced by Einstein's theory. Einstein's paper on the General Theory of Relativity provides mathematical and geometrical models of the space-time curvature to explain gravity. This theory has accurately described astronomical events until now, but it still cannot explain the universe completely.

In the light of Kuhn's arguments, rhetoricians have started to analyze scientific texts for their rhetorical constituents and have strengthened Kuhn's claim that science is a rhetorical construction. The astronomers and the scientists use the authority from their knowledge of the collective data from observations and experiments to make theories as well as persuade other intellectuals and lay people. Thus, all the scientific theories begin with a fixed set of rules and imaginary theories, which are then used to further explain the observations. The rhetorical analyses of scientific texts reveal that science has developed its own objective dispassionate rhetoric. Scientists, including Newton, have been able to invent knowledge and present it to the members of the scientific community and the world at large with the help of symbols and imaginary theories or hypotheses—which are probabilities. Most importantly, extensive debates and controversies take place before and after the publication, and the hypothesis or the theory that is able to convince a higher number of individuals in its field is considered the correct theory.

Newton built his authority in the field of mathematics and natural philosophy by producing new knowledge, and by presenting logical arguments in the *Principia* to refute the prevalent theories and present his own theories as laws. To present his arguments, he sharpened his skills in argumentation. Bazerman writes that before publishing his papers on the optics, Newton diligently read and took notes from the articles published in the *Philosophical Transactions* of the Royal Society to learn the conventions of writing for a journal (88). After publishing and receiving critical responses on his article in the *Philosophical Transactions*, Newton further developed a "form of compelling argument" that "relied on creating a closed system of experience, perception, thought, and representation that reduced opposing arguments to error" (Bazerman 83). We find such persuasive strategies in the *Principia.* In the following analysis, we learn that rhetoric played a significant role in the formulation, persuasion, and acceptance of Newton's laws. Since Newton's laws of motion and his theory of universal gravitation have been immensely popular for over three hundred years, a rhetorical analysis of his work sheds light on the use and subsequent development of the rhetoric of science. Before I begin the rhetorical analysis, I present a brief review of the literature that I have read and used in forming my arguments.

CHAPTER II

LITERATURE REVIEW

Introduction

The discipline of rhetoric has gone through many changes since Aristotle's days. It has been upheld as the *Queen of the Arts* at some points and scorned as *mere sophistry* at others. During ancient Greek and Roman times, rhetoric was practiced for judicial, political, epideictic, and later for educational and religious purposes. In the Middle Ages, classical rhetoric was practiced in an academic context wherein it took a form of syllogistic reasoning that generally had no real-world benefit. In the seventeenth century, until Newton's time, there was a decline in the formal rhetoric. Rhetoric was separated from dialectic and it constituted of flowery language. The development of science, on the other hand, followed rational inquiry and eschewed the frills of language. During the seventeenth and eighteenth centuries, when science was still a part of philosophy, scientists, or the natural philosophers, were encouraged to use plain language. Thus, for a long time, science and rhetoric were considered distinct disciplines despite the fact that science was slowly developing an objective and rational rhetoric of its own. As discussed in the Introduction, this outlook changed after the publication of *The Structure of Scientific Revolutions* in 1962, and there has been a renewed interest and scholarship in the field of rhetoric of science.

In this literature review, I present a brief overview of the studies related to rhetoric, science, and the rhetoric of science, starting from the ancient rhetoric to the current scholarship in the field of rhetoric of science. Since I plan to analyze the *Principia* according to Aristotle's theories, I begin this literature review with Aristotle's *Rhetoric*, which is comprised of three books. After that, I review *History of Astronomy* by George Forbes, *Eighteenth-Century British Logic and Rhetoric* by Wilbur Samuel Howell, *Rhetoric and the Early Royal Society: A Sourcebook* by Tina Skouen and Ryan Stark, and *Newton* by Andrew Janiak. These books shed light on the historical and rhetorical context of the *Principia*. To learn from the current scholarship in the field of rhetoric of science, and to situate my analysis in the modern context, I also review *The Structure of Scientific Revolutions* by Thomas Kuhn, *The Rhetoric of Science* by Alan Gross, *Landmark Essays on Rhetoric of Science: Case Studies*, authored by many scholars, including Bazerman, and edited by Randy Allen Harris, and *Rhetorical Figures in Science* by Jeanne Fahnestock.

In the following sections, I briefly summarize and evaluate all these sources to show how they have been helpful in the rhetorical analysis of the *Principia*. There are a number of significant studies on Newton’s work and rhetoric of science, and it is not possible to review all, but I have cited them whenever I have referred to them in the text.

***Rhetoric* by Aristotle**

Aristotle composed the *Rhetoric* in 350 BCE. The English translation of the *Rhetoric* by W. William Rhys Roberts from 1924 is a standard text followed for its clarity and readability. The *Rhetoric* is comprised of three books. Aristotle begins Book I by claiming that rhetoric is a counterpart of dialectic and that it can be taught systematically. He introduces the artistic modes of persuasion, which are *ethos*, *pathos*, and *logos*. According to Aristotle, *logos*, or persuasion by proof, is the best and it includes examples and enthymemes. Enthymemes are made of probabilities and signs, and the latter could be fallible or infallible. Next, he writes about the three types of rhetoric—political, forensic, and ceremonial, and how they are concerned with future, past, and present.

Book II is in continuation of Book I. The three types of artificial means of persuasion (*pisteis*)*, pathos, ethos*, and *logos* that Aristotle introduces in the first book are described in detail here. Aristotle begins by claiming that an orator's own virtuous character and his benevolent state of mind can make him confident and elevate him among his listeners. For this purpose, an orator should put his audience in an advantageous frame of mind. In the subsequent chapters, Aristotle provides psychological insights into various emotions, and guidance on the ways to produce or diffuse the right kind of emotions in the audience. In the second part of the book, Aristotle deals with the *ethos* and describes how people with different types of characters behave, and how they can be moved/manipulated according to their age and position in the society. He begins the third part of the book by highlighting the relevance of logic in every sphere of life, and then provides in-depth explanations regarding the use of Examples, Maxims, and *Enthymemes* with several examples from various topics, and gives advice regarding their use for invention and refutation of arguments.

Book III on rhetoric is considered a separate work from the first two books because of its style and content. This book deals with style and arrangement in their general form, and with regard to the three branches of rhetoric, which are judicial, deliberative, and epideictic. In this section, Aristotle also writes about the appropriate use of language. According to him, an orator should sound natural; his language should be neither too elevated, nor too pedestrian. He should take care to use appropriate words, suitable epithets, reasonable metaphors and similes, and correct grammar and diction. The prose should be neither metrical nor without rhythm. Aristotle writes about the differences between oral and written styles for political, judicial, and epideictic rhetoric. In the next few chapters, he gives details on how to arrange the parts of speech. We learn about the various parts of speech, such as introduction, statement, narration, proof, interrogation and epilogue, as well as how to compose these for different types of rhetoric. The chapters in the third book draw examples from mythology, historical events, public figures, sophists, and dramatists, among many others.

Thus, Aristotle systemized rhetoric, and his treatises have influenced Western philosophy and rhetoric from his own time until now. Aristotle's philosophy has influenced many leaders and scholars, from the ancient Romans, including Cicero and Quintilian to the Judeo-Islamic philosophers and Christian theologians of the Scholastic tradition of the Middle Ages to the post-Enlightenment era to the modern times. We still learn and teach the appeals to *ethos*, *pathos*, and *logos*, which are useful in persuasive speaking and writing. The psychological insights in the section dealing with *pathos* and the logical arguments in the *logos* section are precursors in their respective fields. As opposed to most of the disciplines, such as science and astronomy, the field of rhetoric, especially regarding the style and arrangement of the written and oral compositions, has remained the same. Aristotle's theories are like scientific tools for deconstructing any text. In this thesis, I have analyzed the text of *Principia* for Newton's use of the rhetorical appeals and the style and organization of the text in the framework of Aristotle's theories.

***History of Astronomy* by George Forbes**

In the *History of Astronomy*, which was originally published in 1909, George Forbes provides information on prominent astronomers and their work from ancient times until his recent past. As such, this book is distinctly pre-Einstein. Forbes begins by writing about the beliefs and theories propounded by the Chaldeans, the Greeks, and those from Eastern civilizations. He calls this period, which includes Ptolemy (130 CE) and Copernicus (1473-1543), the "Geometrical Period." We learn about Ptolemy's treatise *Almagest,* an encyclopedia of astronomy, which remained a popular manual for one thousand years. Ptolemy made many observations on celestial motions believing that the Earth was flat and unmoving. Forbes writes that Ptolemy did not try to theorize or think about the motions in any other terms; he only kept on making observations to predict the motions of celestial objects. As opposed to Ptolemy's theory, which was an established belief during Copernicus's time, Copernicus claimed that the Sun was at rest and the Earth and the planets moved around it. But Copernicus did not break completely from the earlier traditions and believed in the theories of epicycles and circular orbits, which were later proved to be inaccurate.

Forbes further writes about the works of Tycho Brahe (1546-1601), Kepler (1571-1630), Galileo (1564-1642), Newton (1643-1727), and Newton's successors in the second book, titled the "Dynamical Period." Brahe believed in a faulty geo-heliocentric model, but he made extensive observations that benefited future astronomers. Kepler and Galileo used all the observations and data from their predecessors to prove a heliocentric model. Newton further developed the heliocentric model and came up with a theory of universal gravitation. After discussing these astronomers and their theories, in the next two books, Forbes provides information on the instruments of measurement and presents contemporary theories regarding the Sun, the planets and their moons, and comets.

Forbes attributes the progress of science to the accumulation of facts as well as revolutionary thinking. In his exact words, "The progress of human knowledge is measured by the increased habit of looking at facts from new points of view, as much as by the accumulation of facts" (Preface). This is the premise on which Thomas Kuhn has also predicated his book, *The Structure of Scientific Revolutions,* for which Kuhn's book is considered groundbreaking, has caught the attention of scholars and academicians, and has propelled the study of the rhetoric of science. I have reviewed Kuhn's book later in this chapter.

Eighteenth-Century British Logic and Rhetoric **by Wilbur Samuel Howell**

In *Eighteenth-Century British Logic and Rhetoric* (1971), Howell provides detailed information on logic and rhetoric in eighteenth-century Britain. He presents representational writings from this period in chronological order and provides commentary on them. We get an overview of the intellectual activity of a time when the society was in a flux and human knowledge of the world was changing at a fast pace. Even though the writings are presented chronologically, we find that Howell divides the chapters based on the trends in logic and rhetoric in the British society. After the introductory chapter, Howell introduces the readers to Aristotelian scholars and rhetoricians. He claims that despite the disdain for the ancient logic and rhetoric held by the followers of Peter Ramus and Francis Bacon, traditionalists who considered that knowledge could be gained by subjecting ancient wisdom to syllogistic examination also coexisted. Howell calls the traditional Aristotelians, "peripatetics" (13). He gives examples from the writings of some of the Aristotelians, such as Bishop Sanders, Henry Aldrich, and others.

From such examples, we learn that not only Aristotelian logic was strong in the eighteenth century, but also scholars who believed in the power of ornamental language were also influential. While logic was believed to be useful in the discovery of truth and its communication among learned colleagues, rhetoric was considered useful to communicate the truth to the common people. According to Howell, most of the rhetoricians were followers of Cicero and grew up studying Cicero and Quintilian. Howell gives examples from John Ward's lectures, and from John Holmes's *The Art of Rhetoric Made Easy.* The followers of Cicero relied on the five canons of rhetoric, which are invention, arrangement, style, memory, and delivery, in their rhetorical pursuits. Howell then dwells on the British Elocutionary Movement, which flourished for two hundred years in Britain and in America. Proficiency in rhetorical delivery was crucial for the elocutionists as most of them were religious preachers.

While the elocutionists practiced the rhetoric, changes in the theories of logic and rhetoric were slowly taking place. Howell calls the evolved disciplines the *new logic* and the *new rhetoric*. Scholars gradually gave up the art of syllogism and adopted Descartes's and Bacon's art of induction. Thus, the new logic favored investigations and tests of consistency instead of relying on "the authority of metaphysics and revelation" (260). Similarly, the new rhetoric evolved from the old rhetoric by giving up the flourishes and flowery language. The scholars of the late eighteenth century advocated a plain style of writing and speaking. Howell claims that the changes in logic and rhetoric can be "best interpreted as responses to the emergence of the new science" (5). Howell then writes on the style and rhetoric adopted by the members of the Royal Society.

Since Newton lived and worked in the late seventeenth and early eighteenth century, the information in this book is pertinent to this analysis. We learn that society was highly religious at that time, and when people investigated the truth, there was no distinction between religious and scientific truth because in both the cases, investigations were carried out to find the workings of God. Within these parameters, the scholars of the Royal Society tended towards renouncing the authority of the past and looking at the workings of nature through fresh eyes. Thus, the primary texts and the commentaries in this book provide us with knowledge of the context in which Newton was producing his scholarship.

***Rhetoric and the Early Royal Society* by Tina Skouen and Ryan Stark**

While Howell wrote about the voices of the Royal Society in only one section of his book, Skouen and Stark devote their entire collection, *Rhetoric and the Early Royal Society: A Sourcebook* (2014), on the state of rhetoric during the early years of the Royal Society and on its longtime influence. The Royal Society of London was formed in 1660 under the imprimatur of King Charles II. Skouen and Stark's book is a collection of previously printed essays from various scholarly and academic journals. In the "Introduction," the editors claim that the early members of the Royal Society set the tone of scientific discourse. They write that the pioneers of the Royal Society reimagined "the nature of facts, words, print, authority, and audience, among other things" (1). This reimagining resulted in the authorization of scientific experiments and objective writing, which is still followed in modern-day schools and universities. The authors also compare the rhetorical practices of the period and show the influence of scientific writing on the writing practices in other fields.

The book is divided into two sections. The authors in the first section write from the perspectives of "classical rhetoric, early modern science, and religion." They write about the natural philosophers associated with the Royal Society and claim that these philosophers were partial "towards empirical evidence, as opposed to ancient authority," and preferred "things, not words" (1). In the second section, the editors have included articles about the founding members of the Royal Society, such as John Wilkins, Robert Hooke, Robert Boyle, and Thomas Sprat. We learn that Wilkins had attempted to create a universal language, Hooke and Boyle were eminent natural philosophers, and Sprat was selected by the members to write about the formation of the Royal Society.

The introduction and the articles in this book provide insight into the working and thinking process of Newton's contemporaries. We learn how they preferred evidential knowledge and paid attention to their audience. While Ciceronians might have been content with the idea of ancient wisdom and eloquence, the philosophers of the eighteenth century encouraged to read the book of nature, which is itself a metaphor for persuasion. These philosophers set a trend of discovering knowledge through falsifiable experiments and then conveying the results in written communication for their fellow philosophers as well as for the common people. The articles highlight the fact that despite rhetoric being a part of scientific discourse, the evidence-based logical part gradually became dominant.

Newton by Andrew Janiak

In the book, *Newton,* published in 2015, Janiak writes about Newton's life and his work, especially focusing on the intellectual controversies in which Newton was involved. Janiak gives a brief overview of Newton's life from his early life to his years in Cambridge and London. Newton lived in an intellectually exciting time in England when knowledge about the natural world was exploding, and there was no distinction between the different branches of knowledge. Newton led a tumultuous life, dabbling and excelling in most of the disciplines. Janiak argues that despite considerable scholarly interest in Newton's work related to mathematics, physics, alchemy, and religion, there has been less focus on him as a philosopher. Janiak claims that Newton was not a systematic philosopher and that he engaged in philosophical debates only when other natural philosophers attacked his theories and ideas. Therefore, to consider Newton a philosopher, we should read about the controversies and debates, which have been an integral part of philosophy.

Before detailing the controversies, Janiak discusses the definition of the terms "natural philosopher" and "scientist" in the context of the seventeenth and eighteenth centuries. We learn about the struggle among natural philosophers when they were evolving into scientists. Janiak informs us that the term, scientist, was first coined by Whewell in the nineteenth century to distinguish the members of the Royal Society according to their indulgence in experimental philosophy. According to Janiak, Newton's writings reveal that he was a philosopher, who was looking for the laws of nature to understand the workings of its creator, but his approach was different from his contemporaries, hence invoking controversies.

Janiak described the controversy that took place immediately after Newton’s work on optics was published in the *Philosophical Transactions* of the Royal Society. Hooke and Huygens took a strong opposition to Newton’s theory of light in which Newton experimentally deduced that sunlight was made of different colors. The second controversy is about Newton’s debunking of Descartes’s vortex theory. Then Janiak devotes a chapter to Newton’s acrimonious feud with Leibniz, regarding the discovery of calculus.

The debates show us the kind of persuasion that takes place in the field of science when new theories are put out. I also learned from the controversies detailed in this book that one of Newton’s rhetorical purposes in the *Principia* was to prove the absence of ether in the space.

***The Structure of Scientific Revolutions* by Thomas Kuhn**

Despite rhetoric being an intrinsic part of all types of human speech and textual communication, the study of rhetoric remained detached from the scientific discourses until the late twentieth century. A renewed interest in the rhetoric of science is attributed to the publication of Thomas Kuhn's *The Structure of Scientific Revolutions* (1962). Kuhn claims that his studies in the history of science affirm that the development of science has been very different from what has been taught in schools through textbooks and expressed in popular writings. He showed in his book that instead of the commonly held view of the development of science only through the accumulation of knowledge, science has also progressed in paradigms. He calls the scientific pursuits that are carried out under a fixed set of rules and theories, the *normal science* as opposed to the *revolutionary science.* Scientists, who engage in normal science, keep on solving puzzles under a set of given rules and help in the development of science. According to Kuhn, when that set of rules fails to account for any newly discovered or observed natural phenomenon, someone has to come up with a new theory that is better at explaining that event. This requirement for a replacement is also fueled by the development of new technologies through which accuracy of observations is increased. Kuhn calls this change in the set of rules *revolutionary science* because the new data along with all the old data are now explained with the help of new rules. In this way, the continuity of scientific development is interrupted and advanced by revolutionary science.

Kuhn provides examples of the discarded scientific theories, which were once considered legitimate science. He provides many examples from the history of scientific fields, such as astronomy, physics, chemistry, biology, and geology. While the theories of the philosophers from a previous age might now look superstitious and unscientific to us, in their own time those were the best explanations. In the hindsight, we can say that they were all rhetorical constructions.

As a specific example of the scientific revolution, Kuhn writes about the various approaches regarding the theories on the motion of heavenly bodies. He writes about how philosophers and scientists, such as Aristotle, Copernicus, Galileo, Newton, and Einstein have explained the universe through different sets of rules. When one theory is proposed, the followers of the old school naturally resist it, but in the coming years, the new theory replaces the old theory, gradually amassing followers, making the revolution invisible. Kuhn stresses the fact that to follow the new theories, people go through a change in their worldviews. He presents examples of the fierce conflicts and competitions between different schools of thoughts to gain approval and legitimacy from the scientific community.

Kuhn claims that despite the presence of revolutions in the history of science, the scientific facts are presented in the textbooks as if they are the ultimate facts. This is because the books are produced after a scientific revolution is over, the conflicts are settled, and the new belief system has become the new norm. Even though this sequence of revolutions sounds like those followed in the other disciplines including religious beliefs, Kuhn underscores a difference that in science, once consensus is formed after a revolution, there is negligible opposition to it.

Although this book is not specifically on the rhetoric of science, the examples of the use of rhetoric in the success of revolutionary theories paved the way for many rhetoricians and scholars to view science from a rhetorical perspective. Kuhn's explanation of the history of science makes the readers aware of not only the role of rhetoric but also the fact that scientific theories are built on probabilities and are liable to crumble under the weight of new knowledge and discoveries. The fact that scientific theories are accepted after a consensus among the members of a scientific community highlights the relevance of rhetoric since rhetoric is required to build consensus.

***The Rhetoric of Science* by Alan Gross**

Building on Kuhn's argument that scientific facts change when new discoveries aided by new technologies are made, Alan Gross goes out and proves that all scientific facts and interpretations are rhetorical constructions. Gross writes that "the 'brute facts' themselves mean nothing... only through persuasion are importance and meaning established" (4). According to him, even though science depends on rational arguments, the community accepts the best arguments only after consensus. Therefore, building a consensus is a necessary act in scientific development. Gross divides his book, *The Rhetoric of Science* (1990), in three parts; the first part deals with "the relation of rhetoric to science"; the second part is about "style, arrangement, and invention in science"; and in the third part, Gross shows how scientific discourses take place in society.

To highlight the relation of rhetoric to science, Gross writes about the significance of the rhetorical analysis of scientific texts and gives various examples of the use of analogy and taxonomic language in science. According to Gross, scientific texts "are the chief vehicles through which scientific knowledge is created and disseminated" (20). As a specific example, Gross analyzes Watson and Crick's paper on the structure of DNA titled, *The Double Helix,* and analyzes it for the use of rhetorical appeals. Gross shows that Watson and Crick use the narrative structure of the text to build a scientific *ethos* and connect with their readers. This article is also included in Harris's *Landmark Essays on Rhetoric of Science.*

In the subsequent chapter, Gross describes the conventions of style, arrangement, and invention in scientific writings; first, he writes about the prose style used in biology texts in detail, and then about the importance of induction, which has been a hallmark of scientific investigations since the time of Francis Bacon. Gross proves his points with many examples. In one of the examples, he describes Newton’s change of rhetoric from the first edition of the *Opticks* to the second edition. Gross shows that in the second edition, Newton makes a better use of arrangement and rhetorical questions, and adopts non-confrontational style while writing about the other theories. Gross writes that Newton also describes his experiments in detail and suggests that they are replicable. In this way, Newton involves his readers in his discourse. Gross claims that due to the change in rhetoric, the second edition exceeded in its persuasive power.

Another example highlighting the effectiveness of style and arrangement is Copernicus’s struggle to prove the heliocentric model of our solar system. Gross writes that despite Copernicus's publication of *De Revolutionibus* in 1543, other astronomers did not accept his heliocentric model for many years. According to Gross, this was because Copernicus's arguments for the heliocentric model were less compelling. It took a long time for his model to gain acceptance, and it was after sixty-six years that Kepler improved Copernicus’s heliocentric model with the help of additional observations, and presented the results of his investigations in *Astronomia Nova.*

In the last section of the book, Gross explores the trend of peer review and the importance of social norms since the days of the establishment of the Royal Society. He writes about Bacon's vision of cooperative scientific investigations in the *New Atlantis*, Sprat's jingoistic manifesto/history of the Royal Society, and about the Newton-Leibniz dispute. Gross then highlights the prevalence of other priority disputes among scientists and the advantage of rhetoric in such cases.

Thus, Gross provides many examples of the use of rhetoric by scientists in their efforts to present their discoveries to their colleagues and to the world at large. This book underscores the argument that even though scientific writings may seem objective, behind every theory or discovery, there is a story of a struggle for its acceptance as well as to receive credit as a pioneer, and scientists require rhetoric to build and to present their cases.

Landmark Essays on Rhetoric of Science: Case Studies **by Randy Allen Harris**

Harris's collection of "landmark essays on rhetoric of science" or "case studies" was published in 1997. Similar to Gross, Harris also attributes the interest in the studies related to the rhetoric of science to Kuhn's publication of *The Structure of Scientific Revolutions.* After introducing the readers to Kuhn's arguments, Harris writes about the essays in his own book that the "case studies" by various authors exhibit the "suasive greatness, paradigmatic debates, public policy concerns, and composition issues" related to the rhetoric of science (xxix). Harris begins his introduction to the book by giving an overview of the history of rhetoric as well as the history of science. He elaborates on how science has risen in public opinion and has acquired positive connotations while the rhetoric has fallen from its throne, even though the two are intrinsically connected. He stresses science is the subject and the product of an investigation and rhetoric is a tool used to conduct that investigation, and scientists have always used this tool to create knowledge, to argue for their positions, and to persuade others.

Harris claims that the essays in his volume are the most relevant studies in the field of rhetoric of science. Harris divides the essays into four parts. In the first part, "Giants in Science," we learn about the use of rhetoric in Darwin's *Origin*, Newton's *Opticks*, and Watson & Crick's *The Double Helix.* John Angus Campbell analyzes Darwin's rhetoric in the *Origin* and claims that Darwin presented a plethora of evidence, and managed his ethos to persuade the scientific community as well as the lay audience while taking care of the religious sentiments of his era. Gross takes a different approach while writing about Newton's *Opticks.* According to Gross, the second edition of the *Opticks* was more persuasive because Newton changed his rhetoric from confrontational to one of inclusion and demonstration. In the next article, Michael Halloran analyzes Watson & Crick's *The Double Helix.* He claims that the paper is an example of successful rhetoric in which scientific *ethos* is established and a theory is presented in a confident and personal voice.

In the second part, we come across scientific conflicts in the fields of archeology and biology. Jeanne Fahnestock writes about a conflict between archeologists, who hold different views regarding the arrival of humans in North America. Fahnestock presents arguments from both the camps, who change their voice and arguments according to their audience. She highlights how both the sides describe themselves as the new revolutionaries in a Kuhnian sense and the other side as the dogmatic old-school scientists. In the next article, John Lyne and Henrey Howe write about a conflict, in which evolutionary scientists aggressively argue to prove their positions. The authors shed light on the effectiveness of the rhetorical choices made by these scientists. Lawrence Prelli describes another conflict in the essay, "The Rhetorical Construction of Scientific Ethos." Prelli deconstructs the claims and counterclaims of scientists and shows that those who do not follow the norms and standards of scientific inquiry can fall into the category of pseudoscientists.

The third part of the book deals with the use of rhetoric in public discourse for making policy decisions. In these essays, the authors highlight the presence of dialectic and rhetoric, the use of epideictic and judicial appeals, and the roles of *pathos* and *ethos* in scientific discourses. And in the last part, Bazerman and Myers write about the conventions of writing in the field of science. Thus, the essays in the volume cover most of the fields of scientific discourse. This volume is a comprehensive source for knowledge and information on the current scholarship in the field of rhetoric of science. Since my analysis is on the work of one of the giants in the history of science, I specifically gained insights into the process of rhetorical analysis for my project from the sections, "Giants in Science" and "Conflict in Science."

Rhetorical Figures in Science **by Jeanne Fahnestock**

It is interesting that Jeanne Fahnestock begins the preface of her book, *Rhetorical Figures in Science* (1999), by summarizing and commenting on Harris's *Landmark Essays,* which has included her essay on an archeology controversy. It shows how small the world of the rhetoric of science is. Fahnestock clarifies the purpose of her book by informing that even though her book explores the topic of rhetoric in scientific discourses, it is different from the other books on the same topic, as she does not focus on any one specific text or author. She writes that her study is not a rhetorical analysis; rather it focuses on a specific technique used in rhetoric, which is the use of figures of speech. Figures of speech have been used in rhetorical speech to generate and communicate knowledge.

Fahnestock claims that besides metaphors, the influence of other figures of speech in the composition of arguments has not been explored thoroughly. Therefore, in this book, she "investigates the conceptual and inventive power of certain figures of speech other than metaphor and the tropes allied to metaphor" (viii). She explores the rhetorical figures of antithesis, gradatio, incrementum, antimetabole, ploche, and polyptoton in scientific texts from Bacon, Newton, Darwin, and many other scientists. Fahnestock begins with writing about the classical tradition of figures of speech. She talks about the figures as epitomes, saying that some of the figures are attached to certain reasonings and a few others to emotions. Even though there has been an overt effort to make the scientific language plain, we find that scientists have been effectively using the figures of speech to put across their points of view.

Fahnestock writes about the use of the figures of speech in rhetoric since ancient times. For example, she writes about the history, definition, and the modern usage of antithesis. She shares her finding that Aristotle, Darwin, and modern-day scientists have used this figure to highlight their claims in relief against a contrast. A few of her examples are hot/cold, acid/base, human/brute, rational/irrational.

Incrementum and gradatio is another pair of rhetorical figures that Fahnestock highlights. She shows that these two have been extensively used to build or develop theories. Once again, her examples range from the eighteenth- and nineteenth-century scientists to current-day users. She shows that incrementum and gradatio have been used to construct arguments and to build series, which have been extremely helpful in predicting and making new discoveries. This is evident in the discoveries related to the periodic table and the theory of evolution. Similarly, Fahnestock devotes a full chapter to antimetabole, and another chapter to ploche and polyptoton. In both these chapters, she follows the same sequence; first, she gives examples from ancient and historical texts and then draws attention to their usage in scientific texts.

Fahnestock's book introduces readers to the rhetorical figures that are rarely noticed these days. We learn that using such rhetorical tropes not only enhances style but also aids authors in their discoveries and argumentation. The examples in this book teach us to spot these figures in texts, and make us aware of their cognitive significance.

Conclusion

From Aristotle to Fahnestock, rhetoric has been employed in different ways for different purposes at different times in the history and has gradually lost its eminence. Science, on the other hand, has developed into a huge conglomerate after the Middle Ages. From the history of rhetoric and science, we learn that along with the development of science and its rise in academics, there has been a decline in the study of rhetoric.

Although rhetoric together with the classical and Biblical education was once an important canon of Western education, it has been reduced to composition studies since the twentieth century. During the Enlightenment, thinkers, such as Ramus (1515–1572) and Bacon (1561-1626), Thomas Hobbes (1588-1679) advocated for a plain style of communication, and following them, the founding members of the Royal Society advocated the plain style for natural philosophers and disdained ornate language. Following the endorsement by the members of the Royal Society, including Thomas Sprat, John Evelyn, and John Dryden, the use of English instead of Latin was popularized. While Thomas Sprat is credited with laying the guidelines for the natural philosophers, John Dryden is credited with promoting the new simple writing style in English devoid of foreign words.

But rhetoric is not a just ornate language; rather, it is the language itself. According to Aristotle, rhetoric is the use of all available means of persuasion, and scientists have been using what they think is the best form of persuasion, which is an objective and rational way of communication. This trend has become a rhetorical strategy of scientists. Scholars, such as Kuhn, Gross, and Harris argue that science is also a rhetorical construction, and show us how to analyze scientific texts for their use of rhetoric. I learned about the rhetoric of science from all these authors, and have applied my knowledge to the rhetorical analysis of the *Principia,* and before I begin my rhetorical analysis, I present a brief history and summary of the *Principia.*

CHAPTER III

RHETORICAL ANALYSIS OF THE *PRINCIPIA* (PART I)

To analyze the *Principia* for its rhetorical constituents, it is necessary to know about its rhetorical situation. Hence, in this rhetorical analysis, I first write about the text, its author, and his context, and then present the author's rhetorical purpose and his use of rhetorical appeals and strategies. In the concluding part, I present my findings regarding the audience and reception of the *Principia.*

A Brief History and Summary of the *Principia*

Newton started writing about gravity and motion around 1684-86, when the other members of the Royal Society, including Edmond Halley and Robert Hooke, also pursued these topics. Janiak writes that around this time, many natural philosophers at the Royal Society and elsewhere were working on problems related to celestial mechanics. They were trying to discover the "dynamical or causal principles" and "forces" behind Kepler's Laws, as these laws explained the celestial orbits better than the other theories (*Newton* 8). Newton wrote his findings on orbital motions in a nine-page tract "*De Motu.*" Halley was Newton's first reader and he was immediately convinced of its merit. "*De Motu*" was later expanded by Newton and published as the *Principia* in July 1687. Initially, Newton planned to write two books for the *Principia* but ended up writing three, adding the second book as he collected additional material from the pendulum experiments related to the motion of objects in resisting media. Newton added these new findings to provide extra support to make his arguments stronger. In the following years, Newton made further revisions and additions to the *Principia,* and it was published in second and third editions in 1713 and 1726, respectively. The revisions and additions reveal Newton's rhetorical strategies. My analysis is based on Andrew Motte's English translation of the third edition of the *Principia.* Since the first and the second edition are available only in Latin, I have learned about Newton's changes from secondary sources.

In the Preface, Newton introduces the topics of his investigation. He begins by explaining how mechanics and geometry have been related to one another since the ancient times. Here, Newton guides them his readers and explains his philosophy to them in a convincing tone. He presents his work as "the mathematical principles of philosophy" (lxviii).[1] Newton claims that his method of scientific investigation is to study the forces behind the various types of motions and then explain other motions with these findings. He tries to convince readers that there are unknown forces behind the attraction and repulsion between particles, which are responsible for the movement of the terrestrial and the celestial bodies. He admits that even though he is not able to explain all of the natural phenomena with the help of mechanical principles, his method will pave the way for further investigations in the field of natural philosophy, thus indirectly advocating his method of investigation. Immediately after the Preface, Newton provides definitions of the terms that he will use in the rest of the book. These definitions show Newton's inventive power as some of the terms are used in an entirely new way. In the next section,

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[1] English translation of the third edition of the *Principia* by Andrew Motte, published in 1729.

Axioms or Laws of Motion, Newton presents his three laws of motion. Thus, Newton's strategy is visible in the first few pages of the *Principia.* Newton makes sure of explaining the paradigm he has created in which he would be working on the problems.

The first book contains mathematically derived propositions from the laws of motion, all of which Newton had originally written for "*De Motu*." In the first book, Newton specifically provides geometrical evidence for the circular, elliptical, and spiral motions of point masses due to the attraction by other heavier point masses. He names this attraction towards a center "centripetal" force. In this book, Newton's arguments are mostly made up of geometrical construction. In Book II, Newton writes about his experiments and theories on the motion of objects in resisting media. Through these terrestrial experiments, Newton argues against the theory of vortices. Newton's approach in this book was found faulty by his own contemporaries because he did not consider angular momentum. Newton also could not provide any evidence for his claim that vortices were incompatible with Kepler's laws. Although Book II is not relevant these days because of Newton's faulty approach and inconclusive results, his experiments to find the speed of sound and light waves in liquids were instrumental in opening these fields to further inquiry.

Newton wrote a version of "On the System of the World" for Book III in non-mathematical language but decided against publishing it in the *Principia*. Instead, he wrote a section in a challenging form of "mathematical propositions" to keep away troublemakers after Hooke claimed priority over the inverse-square rule (Newton, "Letter to Edmund Halley"). By troublemakers, Newton meant the critics who opposed his theories after superficial reading without understanding his work, or those who did not agree with him. This rhetorical move was made to maintain exclusivity. The original “On the System of the World” was published in Latin (original) and in English (translated by Motte) one year after Newton’s death in 1728. Even without the original text, the third book is readable and easier to understand because, besides the mathematical propositions, Newton presents the applications of his laws in this book; he describes the motions of the planets, moons, comets, and tides of the sea. The book ends with a General Scholium, which is mostly philosophical and is a significant addition to the second and the third editions. To understand Newton’s rhetoric and his scientific method, we will now read about his life and the context in which he was working.

Author and Context

Newton was born on Christmas Day in 1642 on the same day that Galileo died (Biot). When Newton was growing up, England was in political and social turmoil. The hitherto stable British monarchy was facing challenges on many fronts and had plunged into a civil war due to Irish insurrection. During this time, many religious sects proliferated, undermining the religious and political authorities. King Charles I was deposed and beheaded by revolutionaries including Oliver Cromwell, who ruled the Commonwealth until 1660. The civil wars continued for around twenty years and took a toll of around 200,000 people in war casualties and from war-related diseases. The strife ended in 1660 with Charles II on the throne, who established peace and ushered in a period of Restoration. Newton was a young man of eighteen at that time. Further changes took place when the wars were settled. The Royal Society of London was formed under the imprimatur of King Charles II in 1662, bringing the "political and intellectual spheres" together (Janiak *Newton* 2). Thus, while during Newton's early years, England was in chaos, when he entered adulthood, he was fortunate to advance his learnings in a relatively peaceful environment.

During King Charles II's rule from 1660 onwards, there was a renewal in philosophical and political writing due to the king's encouragement of arts and sciences. The prominent philosophical writers of this period were Thomas Sprat, William Temple, John Locke; religious writers were William Penn and John Bunyan; and literary writers included John Dryden, Aphra Behn, and many others. Sprat now represents the writing style adopted by the members of the Royal Society, and Temple is famous for his initiation of the debates on the superiority of Ancient knowledge versus Modern knowledge. While the development of science and the popularity of natural philosophers received a great impetus by the establishment of the Royal Society, some authors also satirized this new development. Margaret Cavendish's protagonist, an empress, in *The Blazing World* (1666) establishes societies of the virtuosos and later dissolves all the societies because they cause factions and divisions. Cavendish was a prominent writer of her period. She attended a meeting of the Royal Society, published on the topics of natural philosophy, and interacted with the other philosophers. Another author, Jonathan Swift, also mocks the natural philosophers and portrays them as working without practical wisdom in his Book III of *Gulliver's Travels* (1726). Newton was friends with John Locke, and despite the fact that Locke did not understand mathematics, he wrote "an anonymous, largely laudatory, review of the *Principia*" (Janiak 9). Thus, we learn that during and following the Restoration, an intellectual sphere was flourishing. In 1988, when King James II was abdicated in the Glorious Revolution, Newton was forty-six and he had just published the first edition of the *Principia*.

Newton grew up to be the most influential philosopher of his age despite the fact that he was born to parents who had no intellectual aspirations. His early life was marred with difficulties, and it formed his idiosyncratic character. Newton's maternal grandmother raised him because his father had died before he was born and his mother remarried and went to live with her new husband when he was three. After the death of his stepfather, his mother returned with her children, and Newton was sent to a school at Grantham, where he studied Latin and Bible. When he completed his education, his mother wanted him to manage their family estate, but Newton was not interested in farming (Janiak, *Newton* 5). At his uncle's suggestion, he was sent to Trinity College in 1661, where he also enrolled at the University of Cambridge.

The intellectual environment at Cambridge was conducive to Newton's growth as a mathematician and a natural philosopher and helped Newton become an authority in his field of work. He learned and practiced natural philosophy well beyond the curriculum of the undergraduate studies. The university followed a traditional curriculum, which included logic, ethics, and rhetoric, "but adventurous and talented students were directed to read the great moderns of the day, who were overthrowing the Scholastic tradition that had reigned for centuries in Europe's great universities" (Janiak, *Newton* 3). Newton and his contemporaries benefited from this open environment and contributed to the

Scientific Revolution, as they were the inheritors of all the astronomical and philosophical knowledge of their predecessor.

Thus, Newton grew up in a period when modern science was evolving and fledgling under the umbrella of natural philosophy. While in England, a group of natural philosophers had formed the Royal Society of England for the advancement of "new sciences" in 1660, in France, *Académie des Sciences* was established in 1666. The education at Cambridge broadened Newton's knowledge and provided him with new insights into the philosophy of mechanics. Newton combined his mastery of mathematics and mechanics/geometry with his knowledge of astronomy.

A study of the astronomical beliefs from Newton's time shows that there was no unanimity on any one model of the solar system when Newton provided dynamical and geometrical solutions to Kepler's laws. Newton had to work hard at persuading his contemporaries because until his time Kepler's findings were not established as laws, and there were "seven different approaches to calculating planetary orbits, all at roughly the same accuracy." Kepler had written about gravitational attraction in his book, but had not given any theory to explain it. Besides these different approaches, "the leading observational astronomer of the second half of the [seventeenth] century, G. D. Cassini, was a Tychonist" who believed in a geo-heliocentric model (Smith). In such a scenario, Newton discovered that Kepler's inverse-square force leads to elliptical orbits, and solved the problem of deviations of planets from Keplerian orbitals by claiming that the interaction of planetary gravitation was responsible for it.

Besides philosophy, mathematics, and astronomy, Newton was also interested in theology, alchemy, and optics. Newton's extensive study of all the branches of knowledge from the Ancients to the Moderns helped him develop his own distinct philosophy. He was able to make connections between the knowledge from various philosophers, and stipulate his own laws and theories at a young age, which made him an authority in his field. Newton was a part of the scientific revolution that was taking place in Europe, and his discoveries became the highest achievements of his era.

Rhetorical Purpose

The text and the context of the *Principia* reveal that Newton's main purpose is to understand God, who Newton believed created this universe according to some definite laws and principles. Newton was greatly interested in theology and alchemy besides natural philosophy. He was involved in the interpretation of the Biblical text and secret alchemical experiments to decipher God's workings besides conducting the experiments and forming theories regarding mechanics in our universe. We learn about Newton's belief in the General Scholium, which he added to the second and the third edition of the *Principia*. In this scholium, Newton writes, "[t]his most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being" (505-506). Newton believes that even though the planets and comets follow the law of gravity, mere mechanics is insufficient to explain the position and regular motions of all the heavenly bodies, and there certainly is a Universal God who put these objects in their right place.

Many philosophers before Newton had considered that mathematics and geometry could help in understanding the natural world and its creator, although "according to the Scholastic natural philosophy …the study of nature was typically separated from mathematics" (Janiak 90). Newton certainly shared Galileo's belief that philosophy in the book of nature "is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures…" (as quoted in Janiak 90). Thus, Newton's main purpose in life is to understand God's working through calculations, geometrical constructions, and their correlation with natural and experimental observations.

Newton's purpose for writing the book is to present his findings and arguments to support his philosophical beliefs. Newton provides rules, laws, and theories as arguments to support a modified heliocentric model that is slightly different from Copernicus's and Kepler's models. Newton investigates and presents natural phenomena with the help of arguments from mathematics, geometry, and experiments. With his refined set of rules, Newton describes and predicts the orbital motions of moons, planets, and comets, and estimates the size and distances of the members of our solar system. Newton expresses this purpose in the Preface in these words:

> Our design not respecting arts, but philosophy, and our subject not manual but natural powers, we consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or impulsive; and therefore we offer this work as the mathematical principles of philosophy; for all the difficulty of philosophy seems to consist in this from the phenomena of motions to investigate the forces of nature… Then from these

> forces, by other propositions which are also mathematical, we deduce the motions of the planets, the comets, the moon, and the sea. (lxviii)

Here Newton provides a distinction between arts and philosophy. According to him, while artistic creations are manual, natural creations are divine and require philosophy to understand. He highlights that gravity and the other forces are examples of natural powers and that his book presents mathematical principles to understand the natural forces. He claims that in the book, he deduces the forces of nature from terrestrial phenomena, and then with the help of these forces and mathematical calculations, he explains the motion of celestial objects.

Newton's another purpose is to contradict Descartes's widely accepted hypotheses of vortices because it could not be confirmed by observations, experiments, or calculations. While Descartes proposed different laws for terrestrial and celestial spheres, Newton provides arguments that the laws that govern the motion of objects on the Earth are the same laws that govern the motion of the celestial objects. Although Newton hugely benefited from Descartes's rational philosophy, he rejected his physics and metaphysics, and eventually, Newton's "experimental philosophy" resulted in scientific revolution.

In the long-run, despite the other setbacks, the *Principia* succeeded in its purpose of popularizing and establishing "experimental philosophy." Newton started a trend in natural philosophy, which was based on experiments, observations, and mathematical calculations. Smith writes that "[i]n addition to viewing the theory of gravity as potentially transforming orbital astronomy, Newton saw the *Principia* as illustrating a new way of doing natural philosophy." Newton describes this new way in the Preface, claiming that "we offer this work as the mathematical principles of philosophy; for all the difficulty of philosophy seems to consist in this from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena" (lxviii). The *Principia* set an example of experiment-based theories and rejected metaphysics. Newton employed Galileo's mathematical style and Boyle's experimental style to explore orbital motions. Newton states the same method which he has stated in the Preface once again on the last page the *Principia* that in his "philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction" (507). The repetition underscores Newton's strong belief and his intent of persuading others. After the publication of the *Principia,* many other scholars and amateurs began to follow the experimental philosophy, which was later called empiricism, and, gradually, it paved the way for a discipline that branched off from natural philosophy to become the experimental science. Thus, Newton succeeded in achieving some of his rhetorical goals.

Newton's use of Rhetorical Appeals

According to Aristotle, rhetoric, the art of persuasion, is useful because many people are not convinced by the knowledge of exact facts, which he calls inartistic proofs. Therefore, a speaker or a writer has to invent artistic proofs, which are appeals to *ethos, pathos,* and *logos*. *Ethos* is related to the character of a speaker, *pathos* is the quality to evoke emotions in the listeners, and *logos* refers to the logical arguments (1.2). The rhetorical analysis of the *Principia* reveals that while *ethos* and *pathos* are mostly constructed before or after the publication, the text of the book is predominantly constituted of logical arguments.

Newton's proficiency in mathematics, his professorship at Cambridge, his invention of a reflecting telescope, and subsequent membership of the Royal Society made him a reputed scholar of his time. He was a highly emotional person, and even though he does not reveal emotions in the text of the *Principia,* in his correspondences he expresses himself freely. This was one of the ways the rhetoric of science diverged from political, judicial, or epideictic rhetoric. Natural philosophers or scientists were required to keep their texts devoid of emotion and maintain certain objectivity. They had to remove their personalities from the presentation of "facts" and let the facts speak for themselves. Thus, in the text, Newton makes arguments from experiments, observations, and mathematical and geometrical constructions to persuade his readers. In the following sections, I present some of the examples of these appeals with regard to the *Principia.* These examples show that despite the emphasis on a plain style, natural philosophers still required rhetoric to convey their findings and express their points of view to persuade others.

Ethos **or Character of the Author**

Appeal to *ethos* is an artistic proof, which refers to the projected character of a speaker. Aristotle argues that a speaker is better at persuading others if he presents himself as a virtuous person and that "good sense, good moral character, and goodwill" elevate a speaker in the opinion of his listeners, and make them favorably disposed to the speaker (1.1). This appeal also includes the authority and credibility of a speaker or a writer, which he acquires from his expertise, and knowledge of a subject. Moreover, while *ethos* can be conveyed through a text or a speech, in the context of publishing scientific papers or books, it is immensely significant to build his or her *ethos* prior to the publication.

Newton was a well-respected mathematician and a natural philosopher even before the publication of the *Principia* in 1687. He became the Lucasian Professor of Mathematics at Cambridge and a Fellow of the Royal Society at a young age. He also built the first reflecting telescope and published his papers on light and optics in the *Philosophical Transactions* of the Royal Society. Even though his optical theory was controversial, Newton became a well-known mathematician and natural philosopher in England as well as in France. He was now an established and an authorized member of a thriving intellectual community. When he began to write about his findings on the movements of celestial objects, he was constantly communicating with the other natural philosophers, including Halley, who was a catalyst in the writing and publishing of the *Principia*. Halley took the responsibility of a publisher because the Royal Society had exceeded its budget. Halley also wrote a prepublication anonymous review in the *Philosophical Transactions,* extolling the *Principia* and its author (Halley).

Newton's authority from his knowledge, his insights, and his meaningful interactions with the scientific community also come across through the text of the *Principia*. Although the text of the *Principia* derives its authority mostly from logical arguments and style, we discern other rhetorical moves by the author, such as invoking the Ancients, referring to his contemporaries, and projecting an agreeable image in the society. In many instances, when new theories from different points of view are presented, the authority of the Ancients or the previous counter theories is not helpful, but when new knowledge is generated by addition to previous theories, invoking the past authorities is advantageous. If an author is counteracting the past authorities, he would be persuasive only if he exceeds the past authorities (Gross 13). Newton invokes the ancients at various places to situate his arguments and take the knowledge of the Ancients and his predecessors to the next level. For example, he begins the Preface with a double invocation of the Ancients:

> SINCE the ancients (as we are told by Pappus), made great account of the science of mechanics in the investigation of natural things: and the moderns, laying aside substantial forms and occult qualities, have endeavoured to subject the phenomena of nature to the laws of mathematics, I have in this treatise cultivated mathematics so far as it regards philosophy. (lxvii)

Here, Newton stressed the relevance of his work by citing the “science of mechanics” of the Ancients and the “laws of mathematics” of the Moderns in investigating nature and claims that he is combining these two things to formulate the laws behind natural phenomena. Newton builds his ethos by showing that he is well-versed in all the discussions, appealing potentially to both camps. He makes efforts to establish the relationship between “mechanics” and “geometry,” and writes, “geometry is founded in mechanical practice, and is nothing but that part of universal mechanics which accurately proposes and demonstrates the art of measuring” (lxvii). Newton explained that geometry is the perfect or ideal form of mechanics; hence, geometry provides exact results. Thus, besides invoking the Ancients and the Moderns, Newton is also making a case for the use of geometry in investigating the laws governing the universe in the first few paragraphs of his book.

As geometry is the main tool that Newton employs to explicate the natural world, he invokes the authority of highly influential geometers and mathematicians from the past several times in the text. And in this process, Newton acquires the *ethos* of their rightful successor. He cited Euclid, a Greek mathematician, who is considered the father of geometry, and Apollonius of Perga, who is famous for his work on conic sections. For example, in Section V, Newton gives a solution to find an orbit when the focus is not given. In his method to find out whether the orbit is a parabola, a hyperbola, an ellipsis, or a circle, Newton confirms that he is using the "famous problem of the ancients concerning four lines, begun by Euclid, and carried on by Apollonius" (135). Newton's mention of these two geometers is an effective rhetorical move because their work had stood the test of time and were highly regarded and well known for their mathematical bare truths.

Besides the geometers, Newton was well aware of the works of all the reputed astronomers, such as Ptolemy, Copernicus, Kepler, and Galileo, and he cites the theorems and data from their works, which makes Newton's own work credible. Here is an example from Proposition IV, Theorem IV in which Newton wants to prove "[t]hat the moon gravitates towards the earth, and by the force of gravity is continually drawn off from a rectilinear motion, and retained in its orbit." He provides data from various astronomers to give the value of the mean distance of the Moon from the Earth in semidiameters of the Earth. Newton writes that the distance is “according to Ptolemy and most astronomers, [is] 59; according to Vendelin and Huygens, [it is] 60; to Copernicus, 60⅓; to Street, 602/5; and to Tycho, 56½” (391). In this example, Newton uses observational data from the different schools of astronomers to support his argument for the Moon’s motion in a heliocentric model. He uses data from Ptolemy, who is a geocentric astronomer, Tycho Brahe, a geo-heliocentric astronomer, and from Copernicus, a heliocentric astronomer. The mention of these astronomers from various periods of time and the comparison of their data make Newton’s argument stronger.

Besides benefiting from the Ancients and his immediate predecessors, Newton develops his *ethos* and supports his arguments by referring to reputed astronomers and physicists of his time, such as Huygens, Halley, and many others. For example, he mentions some of the famous contemporary natural philosophers and astronomers in this scholium at the end of the section Axiom and Laws:

> By the same, together with the third Law, Sir Christ. Wren, Dr. Wallis, and Mr. Huygens, the greatest geometers of our times, did severally determine the rules of the congress and reflexion of hard bodies, and much about the same time communicated their discoveries to the Royal Society, exactly agreeing among themselves as to those rules. Dr. Wallis, indeed, was something more early in the publication; then followed Sir Christopher Wren, and, lastly, Mr. Huygens. But Sir Christopher Wren confirmed the truth of the thing before the Royal Society by the experiment of pendulums, which Mr. Mariotte soon after thought fit to explain in a treatise entirely upon that subject. (90)

These lines are from a scholium in which Newton is describing the corollaries in which he has presented the principles that have been proved by experiments in the past. In this short passage, Newton mentions the Royal Society two times, and he mentions the names of four reputed philosophers. This is not an isolated example; rather, Newton follows this pattern of presenting observational and experimental evidence from his contemporaries throughout the book. I found mentions of about forty astronomers, mathematicians, and natural philosophers in the text. This seems like building a consensus among the scientific community by presenting arguments supported by many professional and amateur scientists to convince the readers.

Besides gaining authority from his learned predecessors, Newton also invokes God in the *Principia.* As most of Newton's contemporary philosophers and readers were deeply religious, they might have identified with Newton's religiosity and his quest for finding divine principles. In the last section of the *Principia*, the General Scholium, Newton invokes God, which provides additional authority to his arguments. Newton writes about his views on God in the Scholium and continues his epideictic rhetoric for three pages. This may not be a conscious rhetorical move on Newton's part, but it might have been certainly influential, considering the religious society in which Newton was living. Newton further writes about the common beliefs about an anthropomorphic God and then declares that "to discourse of [God] from the appearances of things, does certainly belong to Natural Philosophy" (506).

Newton claims that observations, experiments, and mathematics should be employed in doing natural philosophy; and only through natural philosophy we can find

God's design in the universe. Thus, for Newton, science is holy, and his purpose behind the philosophical and scientific investigations is to understand God. While Newton waxes eloquent on the nature, power, and efficiency of God, he remains discreet regarding his anti-Trinitarian belief, expression of which could have landed him in trouble. Religious laws were strict in the seventeenth-century England. All people belonged to the Church of England, which enforced the official doctrine of the Trinity. Therefore, Newton consciously avoids his own views on religion while talking about the Universal God. This strategy to keep quiet about controversial topics is also a way of making the author look dispassionate, rational, and respectable. While in real life Newton was embroiled in many controversies, on the pages of the *Principia*, he avoids talking about any controversy and adopts a non-confrontational attitude.

Another tactic that Newton uses is to hide the loose ends in his theories. According to Smith, Newton makes the "loose ends difficult to see except by the most technically skilled, careful readers." He claims that Newton provides extensive examples to support his claims about exact orbital motions despite the fact that they were complex motions. Despite Newton's successes and claims of deducing celestial motions, many phenomena remain unexplained, but Newton does not write about them. He makes this rhetorical choice because accepting inadequate results might have given his opponents additional reasons for objection. Newton had rejected other mechanical theories for similar reasons. Smith provides evidence from the "Copernican Scholium," that Newton knew orbital motions were more complex than simple ellipses derived by the inverse-square law, but he did not stress this fact in the *Principia*. "Copernican Scholium" is the name given to a passage that Newton wrote after he had sent "*De Motu*" to Haley. This passage was not published until two hundred years. George Smith claims that the "main reason why the *Principia* includes so much beyond the "*De Motu*" tract is Newton's endeavor to reach conclusions that had claim to being exact and true in spite of the inordinate complexities of the actual motions" (Smith). Instead of explaining the complexities of orbitals, Newton devotes more space to arguments for contradicting and disproving the Cartesian worldview.

In Book II, Newton tried to find a theory of motion in resisting media to disprove Descartes but does not mention him in this book. Newton writes about pendulum-decay experiments, in which the velocity of the pendulum decreases because of the resistance by air or any medium in which the pendulum is made to move. He also presented vertical-fall experiments in resisting media. Readers know that these experiments are arguments against Descartes, but he is not mentioned. This strategy of avoiding controversies adds gravitas to the character of the author.

Another example of Newton's maneuvering the readers comes from his presentation of the third law. Newton claims that he was opposed to framing hypothesis and "whatever is not deduced from the phaenomena is to be called a hypothesis," but we have proof that the third law is not deduced from any phenomenon. This claim of induction is made to derive authority from the Baconian tradition of inductive reasoning, in which theories are formed after observations. Philosophers, Howard Stein and Smith, provide evidence from Newton's manuscripts and drafts leading to the publication of the *Principia* that the third law was not formed from induction (Smith; Stein). Newton's changes and omissions from the manuscripts are a part of his rhetorical strategies. The evidence from Newton's manuscripts reveals that he first formed a hypothesis for the third law, and then proved it with terrestrial experiments involving pendulums. This strategy to hide the loose ends via omissions makes the text seem credible. These appeals to authority also act as emotional appeals by putting the audience into a right frame of mind and making them receptive to the arguments provided by the author.

Pathos or Emotional Appeal

In rhetoric, *pathos* refers to the emotions aroused in the listeners by a speaker for his own benefit. Aristotle compares the rousing of emotions of the audience or judges to warping "a carpenter's rule before using it" (Aristotle 1.1), but it does not mean that he is against it; rather, he teaches how to make the rule crooked. He wrote that people who feel different emotions may judge the same case differently; hence, it is imperative to put the audience in the right frame of mind. In the "propositions," Aristotle suggested that speakers should use "friendly feeling" and "confidence" to manipulate the emotions of their audience. Similar to the cultivation of *ethos*, I found that emotional appeals with regard to the *Principia* also fall in two categories; persuasion and debate that went before the publication, and subtle traces of emotions and diplomatic attitude found in the text.

Even though most of the scientific texts and books may seem devoid of emotions or attempts to arouse emotions, much debate takes place before the publication of any project. The author usually makes his case for the publication by proving the relevance and importance of his research or invention. Emotions run high before any publication. While writing on the rhetoric of science, Gross gives examples of emotions in "peer-reviewed procedures" and "priority disputes" (14). He wrote that "[a]nger and indignation are harnessed in the interest of a particular claim; they are part of the machinery of persuasion" (14). Although Gross writes in the modern context, authors of the previous centuries also had to face somewhat similar emotional repercussions. When Newton presented his mathematical calculations in "*De Motu*," he did not face opposition from his peers as the groundwork was already laid; notions of elliptical orbits, the force of gravity, and the inverse-square law were already well known among the members of the scientific community. The only hiccup was from a fellow scientist, Hooke, who claimed that he had given the idea of inverse-square law or "duplicate proportion" to Newton. Hooke expressed his claim strongly to Halley, who then informed Newton in a long letter that Hooke wanted Newton to mention him in the preface to the *Principia* as someone who first proposed the inverse-square law (Biot). Newton replied to Halley that the inverse-square law was a common knowledge for which, he owes to no one else other than Kepler. In the postscript to the letter, Newton wrote the following lines, which reveal Newton's emotional state:

> Since my writing this letter I am told by one who had it from another lately present at one of your meetings, how that M^{r} Hook should there make a great stir pretending I had all from him & desiring they would see that he had justice done him. This carriage towards me is very strange & undeserved, so that I cannot forbeare in stating that point of justice to tell you further, that he has published Borell's Hypothesis in his own name & the asserting of this to himself & completing it as his own, seems to me the ground of all the stir he makes.… he

> may do well in time to consider whether after this new [pro]vocation I be much more bound (in doing him that justice he claims) to make an hon[ourable] mention of him in print, especially since this is the third time that he has given me trouble in this kind. ("Letter to Edmund Halley")

In this postscript to his letter to Halley, Newton is complaining about Hooke to Haley. Newton seems to receive information from a person that Hooke has made an issue about the inverse-square law, claiming that Newton learned about the law from Hooke. Newton then undermines Hooke's reputation by incriminating him of previously stealing someone else's hypothesis and publishing it in his own name. Hooke was, in fact, a reputed member of the Royal Society and responsible for correspondences, but his reputation was marred by such disputes. Newton reminds Halley that this is the third time Hooke is acting in this manner against him and that he was not going to tolerate Hooke. Newton went as far as proposing not to publish his third book of the *Principia*. Halley eventually convinces Newton not to hold back the third book because he believes that the accessibility of the third book will increase the sale of *Principia*. Newton agrees but changes the content and style of his third book. We can gather from this extract how emotionally charged the communication is. We do not find any trace of this kind of acrimony in the text of the *Principia.* In fact, Newton mentions Hooke respectfully as "Dr. Hooke" whenever he uses data and observations from Hooke's experiments.

While Newton vilifies Hooke in this letter written before the publication of the first edition of the *Principia* in 1686, John Flamsteed, who was the first Astronomer Royal, wrote a scathing preface to the *Historia Cœlestis Britannica* in 1717, which was suppressed at that time. In this preface, Flamsteed accuses Newton and Halley of using his unverified observation data without his knowledge (Flamsteed). In fact, as the president of the Royal Society, Newton was engaged in such arbitrary practices. He also had a bitter rivalry with Leibniz and was engaged in a lifelong dispute with him. Such disputes happened behind the scenes, and the published text of the *Principia*, like most other scientific texts, remained didactic, rational, and decisive. Hence, we have to closely examine the text for emotional manipulation.

In the *Principia,* Newton directly addresses his readers at many places. We find a *friendly* prose in the introductory Preface, in the General Scholium, and in various scholia interspersed throughout the middle section. The scholia are written in easy language, and follow the theorems, propositions, and corollaries related to geometrical problems and solutions. We may regard Newton's concluding sentence in the Preface as an emotional appeal; where he writes, "I heartily beg that what I have here done may be read with candour; and that the defects in a subject so difficult be not so much reprehended as kindly supplied, and investigated by new endeavours of my readers" (lxix). This is in its own way a common rhetorical pose in prefaces of the period. Newton writes this sentence at the end of the Preface after telling his readers that he had inserted some of the later findings in the text and had avoided changing the numbering of the propositions; hence, he is apologizing to his readers for their inconvenience. Other than this, the invocation of *pathos* in the *Principia* is through tactics, such as the presentation of Newton as a diligent scientist, suppressing all the traces of disputes and emotions, which we have already discussed in the section on *ethos*. Similarly, while references to God give the author authority, it is also a pathetic appeal. The appeals to authority also change the emotional state of the audience making them extra receptive to the author's arguments.

After looking for examples of *pathos* in the text, I realized that the text of the *Principia* is like a concluding judgment or verdict given after considering all sides of an argument. Therefore, all the debates and disputes occur before a publication, and the *Principia,* similar to a scientific paper, provides logical arguments that are reached after building a consensus among the members of the scientific community. In such instances, even if there are objections from the readers, the author replies to them without emotions in the subsequent editions. This creation of consensus with the help of rhetorical appeals before a publication was a new development in Newton's time. As appeals to *ethos* and *pathos* are often used before a publication, logical arguments or the appeal to *logos* seem to be the most effective tool of persuasion used in scientific discourses.

***Logos* or Logical Arguments**

After establishing his own character and putting the audience in the right frame of mind, a speaker or an author has to argue his points with logical reasoning or *logos.* Aristotle claims that logical arguments are the most important means of persuasion. He writes that arguments can be created from enthymemes, maxims, or examples, and he claims that enthymemes "are the substance of rhetorical persuasion" (1.1). In Book II, Aristotle gives various strategies for creating arguments. The *Principia* can be considered as one long argument against the Cartesian vortex theory, and it consists of several contributory logical arguments. As the examples in the following paragraph reveal, some of Newton's arguments in the *Principia* are distinctly Aristotelian. After the publication of the first edition of the *Principia*, Newton had to deal with many critics, as his theories were not fully accepted by the leading philosophers, such as Huygens and Leibniz, and their followers. To address some of the questions and concerns of his critics, Newton added additional arguments in the second edition, and he argued his case in correspondences with his friends.

While studying Newton's arguments in the *Principia*, we learn that his geometrical demonstrations, propositions, theories, experiments, and observations are similar to Aristotle's topics for rhetorical inventions. According to Gross, "observation, measurement, prediction, mathematization" are the special topics for argumentation in scientific discourses (11), and "all experimental generalizations illustrate reasoning by example" (12). In Book I, Newton gives geometrical explanations for orbital motions. He defines "force" in terms of distances with the help of diagrams, which is a persuasive strategy. He claims that "[t]hose things which have been demonstrated of curve lines, and the superfices which they comprehend, may be easily applied to the curve superfices and contents of solids," meaning what he establishes with the help of lines, curves, and points can be extrapolated to the force and orbitals of the solid spherical planets or moons (102). In this example, Newton depicts the constant gravitational attraction of a planet towards the Sun with a geometrical diagram, which depicts an elementary form of calculus.

Despite the fact that Newton could not find laws of resistance forces from his experiments due to his faulty approach in Book II, his experiments remain examples of scientific arguments. In Book II, Newton writes about the motion of objects in resisting media. Janiak writes that Newton shows "how philosophers could employ various mathematical and experimental methods in order to reach conclusions about nature" ("Newton's Philosophy"). Newton conducts these experiments to prove that the celestial objects move in a non-resisting medium, meaning that the planets are not carried by fluid vortices. Besides his own experiments, Newton profusely uses data and experimental results from the other natural philosophers.

We also find arguments from comparison, definition, cause and effect, experimental generalizations, examples, and enthymemes, all of which Aristotle commends for creating effective arguments. Newton introduces many new concepts, such as *vis inertia*, impressed force, centripetal force, and accelerative and motive quantities of centripetal force. In the Preface, Newton compares geometry with mechanics to establish his reasoning behind the use of geometry in formulating the laws of orbital motions. Immediately after the Preface, Newton gives definitions of major terms that he thinks the readers might encounter for the first time or might find difficult to understand. The definitions increase the accessibility of the text. Aristotle writes that successful rhetoricians "define their term and get at its essential meaning, and then use the result when reasoning on the point at issue" (2.23.7). The *Principia* begins with eight definitions, and at the end of the definitions, there is a scholium with additional definitions. The first definition is about "quantity of matter," now called mass, and the second definition is "quantity of motion," now termed momentum. There are two of the basic terms used in the study of physics

Newton makes another distinctly Aristotelian argument in Book III when he presents rules and then qualifies them in the succeeding passages. According to Rule II, "to the same natural effects we must, as far as possible, assign the same causes" (384). This rule is pure rhetorical construction, as it does not have any theoretical basis. Newton expounds this rule of assigning same causes to same natural occurrences with the help of these examples: "As to respiration in a man and in a beast; the descent of stones in Europe and in America; the light of our culinary fire and of the Sun; the reflection of light in the earth, and in the planets." Which means that there is the same cause for the respiration among humans and animals; there is the same force that brings down a stone in Europe, and another stone in America; the fire in a kitchen and the fore of the Sun are same; and the light reflected by the Earth is similar to the light reflected by another planet. Besides fulfilling the purpose of explaining the rule, these similes are beautiful stylistic constructions that make the rule memorable.

According to the next rule, Rule III, "[t]he qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever." This rule is also an argument with a weak premise. Newton then describes this rule that the "extension, hardness, impenetrability, mobility, and *vis inertiae* of the whole, result from the extension, hardness, impenetrability, mobility, and *vires inertiae* of the parts" (384). This rule is made up by Newton based on common sense and is not based on any experimental result. Smith writes, "Newton's phrasing carries no suggestion that these rules yield truths or even a high probability of truth." These rules rely on rhetorical constructions, but such arguments are helpful as research tools for further discovery.

While we are studying the use of different types of arguments in the *Principia,* how can we forget Aristotle's enthymemes? An enthymeme is an argument in which either the premise or the conclusion is omitted to increase the efficacy of the argument. Readers or audience are expected to complete the argument from a common belief, or a tradition, or common knowledge. When I first came across the phrase, "I frame no hypotheses (*hypotheses non fingo*)" in the following paragraph from the General Scholium towards the end of the book, I did not understand its significance:

> But hitherto I have not been able to discover the cause of those properties of gravity from phaenomena, and I frame no hypotheses; for whatever is not deduced from the phaenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. (506-507)

I learned the true meaning of this phrase when I realized that this argument refers to Newton's refutation of Descartes's and Leibniz's deductive methodology as opposed to what Newton claims to be his own inductive approach. Since Newton does not mention either Descartes or Leibniz in the General Scholium, the whole scholium reads like an enthymeme and makes Newton's argument stronger. By mentioning "occult qualities," Newton also seems to be getting back at those who accuse him of reverting to occultism in proposing the theory of universal gravitation.

We find logical arguments on most of the pages of the *Principia,* and these smaller arguments support Newton's main argument against the theory of vortex. According to the vortex theory, planetary motions are caused by vortices of fluid, or ether, which fills up space also called plenum. Leibniz and Huygens, two of Newton's leading contemporary philosophers also believed that force between two objects can transfer only when they have physical contact, hence for the Sun to attract the planets or for the Earth to attract the Moon, space should be filled with some continuous substance. But Newton opposed this hypothesis because the presence of a substance or ether was incompatible with his calculations. Newton's critics, on the other hand, thought that even though he was providing advanced mathematical calculations and geometrical explanations, he was not following the rules of mechanical philosophy, in which force could be carried only through matter. Two years after the publication of the first edition of the *Principia*, Leibniz wrote an essay and a letter directly to Newton, in which he commended Newton's discovery of gravitational attraction as a cause of planetary motion in Kepler's elliptical orbits, but he reiterated that according to the mechanical philosophy, there should be some fluid medium to carry the gravitational force. Leibniz claimed that the vortex theory is better at supporting the inverse-square gravitational force in the solar system (Janiak "Newton's Philosophy"). Newton, on the other hand, had concluded that the presence of any fluid medium or ether would result in irregular motions of the planets, satellites, and comets. After receiving Leibniz's letter, Newton replied to him:

> For since celestial motions are more regular than if they arose from vortices and observe other laws, so much so that vortices contribute not to the regulation but the disturbance of the motions of planets and comets; and since all phenomena of the heavens and of the sea follow precisely, so far as I am aware, from nothing but gravity acting in accordance with the laws described by me; and since nature is

> very simple, I have myself concluded that all other causes are to be rejected and that the heavens are to be stripped as far as may be of all matter, lest the motions of planets and comets be hindered or rendered irregular. (qtd. in Janiak, *Newton* 122)

In this extract, Newton argues with Leibniz that all movements in the heavens and the tides of the sea are highly regular and exactly follow his laws. He claims that if the fluid vortices produced celestial motions, they would have caused disturbances and irregularities. He reiterates his belief that there are very few rules in nature, meaning that the simple laws that govern the terrestrial motion also govern the heavenly motion.

Newton rejects Leibniz's suggestion to include the vortex theory in his gravitational theory. Rather, as a result of the objections made by Leibniz and his followers, and the poor reception of the first edition, Newton sharpens his arguments against vortices in the second edition of the *Principia.* He adds the General Scholium at the end of Book III, which refutes the vortex theory in strong terms. Newton begins the General Scholium with these words: "The hypothesis of vortices is pressed with many difficulties…" (503). Leibniz, Huygens, and others believed that Newton was using gravity as an occult quality, abandoning the rules of mechanical philosophy.

In his reply to his critics, Newton broadened the definition of mechanical philosophy and argued by comparing gravity with other qualities, such as hardness, inertia, and extension that were also inexplicable in mechanical terms and were not considered occult qualities. Newton argued that

> no man ever attempted to explain these qualities mechanically, or took them for miracles or supernatural things or fictions or occult qualities. They are the natural, real, reasonable, manifest qualities of all bodies seated in them by the will of God from the beginning of the creation and perfectly incapable of being explained mechanically… I know not why he should be said to introduce miracles and occult qualities and fictions into the world. For Mr. Leibniz himself will scarce say that thinking is mechanical as it must be if to explain it otherwise be to make a miracle, an occult quality, and a fiction. (qtd. in Janiak, "Newton's Philosophy")

After comparing gravity to the properties of matter, Newton further compares it to "thinking" and he attributes to God what he could not explain. Newton seems to despise the use of the terms, miracle, occult, and fiction against him because they carried negative connotations, and were considered regressive by the members of the scientific community or the natural philosophers.

Newton's General Scholium is a forceful argument against those who objected to the concept of gravitational attraction devoid of any mechanical explanation, and this debate lasted until the end of the eighteenth century in one form or the other (Janiak "Newton's Philosophy"). Despite or in spite of the debates, Newton consolidated his position by convincing his colleagues that many natural phenomena, such as movements of the planets and comets, tides, and precession of the equinoxes could be best explained with the mathematical calculations based on his laws. With regard to the cause of gravity, Newton argues that it is similar to the workings of the nervous system of animals which was also a mystery at that time, and declares that "these are things that cannot be explained in few words, nor are we furnished with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this electric and elastic Spirit operates" (507). This explanation is entirely unscientific but might have convinced many of Newton's readers.

Newton's reputation increased in the subsequent decades when his prediction of the oblate shape of the spheroidal Earth came true, and his theory of gravity was used to explain the Moon's orbital precession. If Newton had not provided arguments in the text of the *Principia,* and not participated in the debates to convince his fellow philosophers, it is hard to imagine that his theories would have been accepted and furthered by the subsequent generations. It was possible that someone else came up with some other theory in different terms that could have explained the natural world equally convincingly. All these arguments and disputes underscore the necessity of rhetoric in science. In the next section, I write about Newton's use of invention, arrangement, style, memory, and delivery with respect to the *Principia,* which further served his rhetorical purpose.

CHAPTER IV

RHETORICAL ANALYSIS OF THE *PRINCIPIA* (PART II)

The Five Cannons of Rhetoric

Aristotle wrote about style and arrangement in Book III of the *Rhetoric*. Cicero later canonized these as invention, arrangement, style, memory, and delivery. The five canons can be used for generating or analyzing a speech or a text. The following study reveals how Newton used these in the composition of the *Principia.*

Invention

Invention with respect to the *Principia* includes Newton's education in the field of natural philosophy as well as his discoveries. Newton's education commenced at the Grantham School and reached its pinnacle at the Trinity College, Cambridge. At the Grantham School, Newton learned Latin and theology, and he was involved in creating many mechanical devices, such as a windmill and a sundial (Biot). At Trinity, he mastered all the seventeenth-century mathematics in one year and started to invent new theorems and new ways of calculation. Newton’s interactions with his teachers, especially Barrow, and later with the other natural philosophers, such as Huygens, Hooke, Halley, and Flamsteed also played a big role in the development of his theories. We learn about Newton's thought process and working style from his notebooks, which he kept during his school years and beyond, and these notebooks, transcribed in various forms in English, are now available online.

In one of Newton's notebooks, now published as “Newton's Waste Book Part I,” Newton works on many mathematical problems and writes about his experiments. We find long-winded multiple-page calculations, which are difficult to understand by uninitiated readers. Newton also depicts his experiments with the help of diagrams and illustrations. Some of the experiments are found in the *Principia* as well. For example, one of the “[e]xperiments about the resistance of things falling in water,” which Newton describes with the help of elaborate mathematical calculations in the “Waste Book” is described in the *Principia* in simple and formal language on page 347. Thus, Newton uses his notebooks for developing ideas and is careful to present them according to his audience in the published book.

We come across Newton's inventive aptitude in his “philosophical notebook” as well, especially, in a passage called *Quaestiones quaedam Philosophicae.* The notes in this passage reveal Newton's earnest study of several philosophers. Among the forty-five topics that Newton writes about, we find his notes on the topics related to the *Principia* under the headings, “Of Gravity and Levity,” “Of time & Eternity,” “Of Motion,” “Of the Celestiall matter & orbes,” “Of the Sunn Stars & Plannets & Comets,” “Of Violent Motion,” “Of Earth.” These entries show that his views were beginning to take shape by his readings, questioning, thinking, and writing. Newton started to think about the issues that were precursors to his mature philosophy. Newton not only followed these authors, rather he also jotted down his own views, refuting some of them when he did not agree to their theories or found them lacking in some aspect.

Newton's inventions presented in the *Principia,* as mentioned earlier, are his improvements to the existing laws of motion and theory of gravitation. To reach these conclusions, Newton invents many mathematical and geometrical constructions; he also invents and conducts many experiments; and finally, he invents arguments to present his findings and arranges them in written form.

Arrangement

In the presentation of the *Principia*, Newton follows the prototype of Euclid's *Elements*, which is a treatise on geometry from 300 BCE. During the Renaissance and the Enlightenment, the philosophers tended to reject the ancient knowledge that was preserved by the Scholastics and were apt to investigate nature with fresh eyes. But Euclid's *Elements,* despite being ancient, remained highly relevant as the geometrical facts presented in it were considered the ultimate truths. The *Elements* was not only an exemplar of truth, but it also showed how to organize and present knowledge. For Newton to follow Euclid's style in the *Principia* is a judicious rhetorical move although this could have been a natural style adopted by him because he learned geometry from the *Elements*. This latter argument is endorsed by Whiteside, who writes that Newton's use of Euclidean organization style, using "'Propositions', 'Theorems', 'Problems', 'Lemmas' and 'Scholia' are mere expository frameworks inherited from his enforced study, as a subdued Trinity College undergraduate, of Isaac Barrow's 1655 Cambridge edition of the *Elements* and they are manifestly retained in his own subsequent mathematical writings purely as a literary convenience" (118). Nonetheless, Euclid's vocabulary and arrangement style might have made the *Principia* acceptable and accessible to those who were familiar with the *Elements.*

Newton began the *Principia* exactly the same way as the *Elements* by providing definitions, axioms, and laws before he begins the geometrical constructions that depict mechanics. Following Euclid's style, he mathematically derives theorems and problems from the laws of motion. Thus, the *Principia* begins with “Preface” followed by “Definitions” and “Axioms or Laws of Motion” and “Corollaries.” After these preliminaries, the rest of the book is divided into three “Books.” In the first book, Newton writes about the mechanics of motion in an unresisting medium, such as vacuum. In the second book, he writes about the motion of objects in resisting media. In both books, he presents experiments and mathematical derivations under the numbered headings of “Lemma,” “Proposition,” “Theorem,” “Problem,” and then these mathematical derivations are expressed in non-mathematical terms under the heading of “Scholium.” This rhetorical move of categorizing is useful in making text accessible and memorable for readers. In the third book, Newton extends the laws and findings of the first two books to present his “Rules of Reasoning in Philosophy,” and describes their applications in “Phenomena, of Appearance,” which includes the motion of moons, planets, comets, and the seas. Once again, we come across various propositions and theorems in a section named “Propositions,” and then the *Principia* ends with a “General Scholium.” The organization in the *Principia* is easy to follow and the information and knowledge grow organically from easy to difficult in a style similar to the *Elements*.

Thus, both Euclid and Newton presented their theories and laws in a similar organization, and people, at some point, accepted both these books as repertoires of the ultimate truths of nature (Smith). Even when Euclid's and Newton's basic concepts were proved wrong after Einstein proposed a curved space-time, their works still remained relevant to our understanding of the world on a smaller scale.

Style

Despite the fact that the *Principia* is considered a difficult text, Newton makes many stylistic efforts to deliver his arguments in easy style. As we have already learned, Newton follows the arrangement and style of the most reputed and revered treatise of his time, the *Elements*. Newton wrote the *Principia* in Latin, which was the language of educated people, and as he was a professor at a university, his tone was naturally didactic. For example, in the Preface, he adopts a friendly didactic style and familiarizes the readers to his way of doing natural philosophy. First, he highlights the definitions and the relationship between geometry and mechanics because these are the two basic tools Newton uses to construct his laws and theories. Then before he begins Book I, he follows Euclid's example and presents a set of axioms and laws from which he derives all the following theorems. After each mathematical section of Proposition / Theorem / Problem, Newton describes the procedures and results in a non-mathematical language in a scholium, which makes it accessible to the non-mathematical readers.

The sections of the *Principia,* which contain mathematical explanations, have no other style than "if-then" derivations and commands for constructing diagrams and inferring the relationship between the different parts of the diagrams. In these mathematical sections, Newton follows the plain objective style, which was hailed as a tool for communication in the field of natural philosophy. It constitutes passive voice that is independent of the author's interference. Thomas Sprat, who was assigned to write a history of the Royal Society during its founding years, describes the rhetoric of natural philosophers and distinguishes it from the rhetoric of the Scholastics and Alchemists. Sprat writes that the natural philosophers should

> reject all the amplifications, digressions, and swellings of style: to return back to the primitive purity, and shortness, when men deliver'd so many things, almost in an equal number of words. They have exacted from all their members, a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the Mathematical plainness, as they can…. (113)

As is evident from this digressive passage, Sprat, while writing against the use of ornamental language, shows his own expertise in the use of rhetoric in which he was well grounded. But obviously, these authors were reacting against too much rhetorical amplification. While Newton follows the plain style for writing the mathematical parts and laws and definitions, in the successive paragraphs and scholia, he explains the mathematics using similes and examples. The mathematical part has its own style, which is similar to the rhetorical device of gradation.

Newton systematically develops the concepts and theories gradually from easy to difficult, not only in the organization of the whole book, as discussed earlier, but also on the level of smaller sections. He proceeds from easy demonstrations to the difficult ones, extrapolating his geometrical constructions, experimental examples, and examples from daily life to explain the larger phenomena of the celestial sphere. A diagram showing an object move from point P to point Q is then explained as a part of an orbital in which the object moves around another attracting force. The path of the object is later extrapolated either on the Moon's orbit around the Earth or on a planet's orbit around the Sun.

Besides geometrical constructions, Newton also provides various terrestrial experimental examples to explain the celestial phenomena. The reason behind such explanations is the fact that it was impossible to prove celestial movements with experiments in the space. Some of the terrestrial experiments mentioned in the *Principia* are conducted by Newton, and quite a few he cites from other people. Unlike Newton's alchemical experiments, the mechanical experiments are simple ones. In these experiments, Newton first wrote about the motion of objects, such as pendulums, strings, balls, or vessels on the Earth, then compared their motion with the members of our solar system, and then proved that the forces acting in both the instances are similar. In one experiment, to describe the motion of an object as a whole compared to the motion of its parts, Newton wrote about an experiment in which he hangs a vessel filled with water with a twisted rope (81). When the rope untwists, initially, the surface of the water in the vessel remains plain due to inertia, and after the motion of the vessel is transferred to water, it starts to form a concave shape, and then after a while, the vessel reaches its maximum velocity and the water comes to rest relative to the vessel. After describing this experiment, Newton wrote about the celestial system in these words:

> And therefore in their system who suppose that our heavens, revolving below the sphere of the fixed stars, carry the planets along with them; the several parts of those heavens, and the planets, which are indeed relatively at rest in their heavens, do yet really move. For they change their position one to another (which never happens to bodies truly at rest), and being carried together with their heavens, partake of their motions, and as parts of revolving wholes, endeavour to recede from the axis of their motions. (81)

Here Newton is describing a system in which the stars are fixed and our solar system moves along with the planets. He writes that the planets seem relatively at rest, but they really move. Since the planets are parts of the solar system, they recede from their axis of motion. Meaning that when the solar system revolves like a bucket filled with water, the planets behave like receding water. Newton follows this pattern of extrapolation to predict celestial rules from terrestrial experiments throughout the *Principia*.

Besides the experiments, Newton also relies on similes and analogies from daily life. Newton's celebrated apple is not mentioned in the *Principia,* rather we learn about gravitation from stones, leaden balls, and projectiles falling on the Earth from various heights. From these examples, Newton described orbital motions of celestial bodies (75). He declared that the force that brings the objects down to the Earth is also responsible for the Moon to revolve around the Earth, and the same force holds the planets in their orbits around the Sun.

Another figure of speech that Newton uses abundantly is the antithesis. Antitheses make arguments stronger by presenting contrasting or opposite ideas together. In one example, Newton writes about manual mechanics and natural mechanics. At another place, he defines “time, space, place and motion” not in common terms, but in terms of “absolute and relative, true and apparent, mathematical and common” (77). The juxtaposition of these terms helps in the explanation, and make readers grasp the idea easily.

Memory and Delivery

In writing, memory plays a significant role, albeit a different one than oratory. A complex book, such as the *Principia,* is possible only due to it author’s retention of the knowledge from his predecessors and contemporaries, and his ability to connect different theories. Moreover, the results of one’s inventions have to be stored either in memory or in written notes, and when we write notes, we have to remember where we have stored the notes. Newton’s memory helps him devise new theories out of the vast pool of knowledge from the Ancients to the Moderns. As mentioned in the previous sections, we find references to Aristotle, Apollonius, Copernicus, Galileo, Kepler, and many others in the *Principia*. In this process, the author also appeals to the memory of his readers. To help the readers understand and retain the information, the author has to organize the text and include devices, such as explanations and repetition of examples. The text of the *Principia* is many times larger than the oral compositions of its period, but the author and the readers have the benefit of written notes, hence the knowledge and information is incremental. Newton first composed nine-page tract and then enlarged it into a book. In the subsequent editions, he added additional content to the book, which included new observations and explanations. Newton's drafts and notes give us glimpses into his evolving style of presentation or delivery of the final text.

Delivery is closely related to the rhetorical appeals, and the organization and style of a text, which we have already discussed in detail in the previous sections. The publication and the promotion of a book are also parallel to the canon of delivery in the oral tradition.

Audience and Reception

When Halley first published the *Principia* under the imprimatur of the Royal Society, Newton had a receptive audience of natural philosophers in London waiting for the publication. Newton knew exactly what kind of audience he was writing for and had an idea about the reception of his book. His optical publications in the *Philosophical Transactions* of the Royal Society had caused controversies; therefore, he was highly concerned about the negative reception and objections by those who did not understand his work. Newton writes in the first paragraph of Book III:

> … I had, indeed, composed the third Book in a popular method, that it might be read by many; but afterward, considering that such as had not sufficiently entered into the principles could not easily discern the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed, therefore, to prevent the disputes which might be raised upon such accounts, I chose to reduce the substance of this Book into the form of Propositions (in the mathematical way), which should be read by those only who had first made themselves masters of the principles established in the preceding Books…. (383)

Newton writes that initially, he had composed the third book in a non-mathematical language so that more people could read it. But he realized that people who do not understand his principles would not be able to grasp the results and would oppose his theories because they have been indoctrinated with the previous theories. He seems to be annoyed with people who criticize his work. He is eager to avoid disputes; therefore, he makes the third book exclusive and decides against the simple version. Newton wants to reach out only to the members of the exclusive club of leading natural philosophers who could understand his mathematics. Mathematics was Newton's strong point. The other leading philosophers who criticized Newton for his physics did not find fault in his mathematics.

Newton respected the leading philosophers Huygens and Leibniz, who were his eminent audience, for their work and discoveries, and initially corresponded with them on friendly terms. And there was also Hooke, who upset Newton by making a priority claim for the inverse-square law. But Newton also had staunch supporters in Halley and the other authorities at the Royal Society. When Newton shared his concerns regarding Hooke with Halley, Halley managed to calm down Newton and encouraged him to complete the *Principia*. Halley also wrote an anonymous prepublication review of Newton's *Principia* in the Ph*ilosophical Transactions of the Royal Society*, in which he wrote that the "incomparable Author" has discovered the "Principles of Natural Philosophy," and that the author has accomplished so much "that he seems to have exhausted his Argument, and left little to be done by those that shall succeed him" (291).

In such an atmosphere, when the *Principia* came out, even though very few people to understood it entirely, it was celebrated in England. Janiak writes that "Newton's ideas and methods were certainly most influential in England, where there grew to be a strong 'Newtonian' movement—also called the 'experimental philosophy' program—by roughly 1700" ("Newton's Philosophy"). Although the *Principia* was considered a difficult book containing advanced mathematics, it was made accessible by a group of interpreters, who wrote about the book in simple terms. Cohen and Westfall write that "[t]his group included Henry Pemberton, a medical doctor skilled in mathematics who had edited the third edition of the *Principia* under the author's direction, [and] Colin Maclaurin, a mathematician whose fame today rests largely on the infinite series that bears his name" (xiv).

The reception was not as wholehearted at other places in Europe. After the initial lukewarm reception in France, Newton's work was popularized by "Voltaire, who learned his Newtonian physics from the Marquise du Chastellet, the translator of the *Principia* into French." Chastellet's translation remained "the best vernacular version of Newton's masterpiece for two centuries" (Cohen and Westfall xiv). The other Continental philosophers, Huygens and Leibniz, welcomed Newton's book initially, but they decried the lack of rational mechanical foundation. They thought Newton was reverting to occult practices of the Medieval period, which the Cartesian philosophy had replaced. They appreciated Newton's mathematics, but they were not convinced by his attempts at describing the universe with mere geometry (Maglo 149). These philosophers advised Newton to include the vortex theory in his philosophy, but Newton rejected their advice. Thus, the scientific community on the Continent did not accept Newton's *Principia,* especially, his theory of gravitation until the late eighteenth century, as English and French scientific institutions held rivalry. It also did not help that Newton's theories predicted certain phenomena only to an approximation.

But the fact that Newton was able to persuade many of his contemporary philosophers worked in his favor because his followers were able to further his theories and persuade others. A few decades after Newton's death, a new generation of French scientists and mathematicians started to adopt Newton's mathematical analysis, and some of them, such as Varignon made great advances. Maglo writes that "from the 1730s to the 1760s" was "a period of revision… when Maupertuis, Euler, d'Alembert, Clairaut, and to some extent the Bernoullis, reinterpreted the new physics" and after that began "a period of standardization when Lagrange and Laplace codified "Newtonian" mechanics in its definitive form" (137). These scientist/philosophers were able to prove Newton's claims regarding the Earth's oblate figure and solved the discrepancies in the motion of the Moon, and in the motion of Jupiter and Saturn besides other findings; these discoveries reinforced the acceptance of Newton's laws. As a result of the applicability of the gravitational theory, scientists stopped questioning the cause of universal gravity. Newtonian physics kept on developing by addition of smaller discoveries, observations, and calculations by Newton's followers until the early years of the twentieth century, when it paved the way for Einstein's theory.

CHAPTER V

CONCLUSION

Newton's *Principia* has been an influential text in the history of science since its publication in 1687. This rhetorical analysis is a small effort in analyzing the landmark historical scientific text. By analyzing the *Principia,* I learned how Newton created knowledge and how the scientific community accepted it. Newton derived knowledge from both the Ancients and the Moderns, but he formed his own distinct philosophy in which he argued that a method including observations, experiments, and mathematical calculations was the best way to understand the workings of the universe. Newton constructed his theories from a strong belief that geometry is the perfect form of mechanics and it should be used to understand terrestrial and celestial mechanics. According to one of the basic requirements of rhetoric, people can persuade others only if they strongly believe in their own arguments.

Newton's rhetorical strategies in the *Principia* were successful in convincing many of his contemporary natural philosophers. His followers and interpreters further helped in popularizing the *Principia*. In England, the *Principia* was hailed as an epitome of knowledge. Alexander Pope expressed the sentiments of his era in these words: "Nature and Nature's Laws lay hid in Night/ God said, 'Let Newton be!' and all was light." In the rest of Europe, it took persuasion by a generation of scientists to make Newton's theory acceptable. This shows that if the majority of people do not accept a new theory on its advent and only some of the readers and colleagues are persuaded, these followers further help in convincing others. This underscores the belief that scientists require rhetoric to persuade others, but scientific rhetoric is slightly different from Aristotelian rhetoric.

This analysis of the *Principia* in the framework of Aristotle's rhetorical theories revealed some differences between scientific rhetoric and Aristotelian rhetoric. I noticed that scientific texts are like judgments rather than arguments because usually they are published after building consensus among the members of an immediate scientific community. While Newton received and incorporated feedback from his editors, in modern times, the peer review serves this purpose. Another difference is due to the fact that scientists believe that their main aim is to provide information, so their texts should be usually devoid of passion and stylistic constructions as opposed to the rhetoric related to Aristotle's special topics. However, scientists and those who benefit or suffer from their inventions are all human beings, and they go through the same emotions. Thus, scientific rhetoric could benefit from Aristotelian rhetoric, because Aristotle advocates taking the behavior and emotional state of different types of personalities into account while practicing rhetoric.

Further exploration of Aristotle's rhetorical appeals in the context of the *Principia* reveals that one crucial aspect that helped in making the text popular was Newton's authority in the field of mathematics and natural philosophy. Newton's expertise made his contemporaries pay attention to his work. There is no shortcut to becoming an authority on any subject. Young scientists have to follow stringent coursework and laboratory work before they can research independently on any topic. They have to build their *ethos* with their publications in scholarly journals. Building *ethos* in the scientific field is similar to the other fields of knowledge.

A distinctive feature of the scientific texts is the abundant use of logical arguments. In the *Principia,* Newton provides mathematical constructions and experiments as arguments and then explains them with examples from daily life. He describes force, velocity, mass, time with the help of geometrical constructions, and then extrapolates them to the celestial mechanics. Following his examples, scientists have created a world of standardized language and symbols, and make extensive use of taxonomy This shows that science has its own distinct rhetoric, which is used to create knowledge as well as to share it with others.

We learn from Newton's notebooks that he organized his readings and thoughts to make connections and invent theories. He organized the *Principia* in a traditional format on the lines of Euclid's *Elements*, which made the *Principia* easy to follow. Organization along with taxonomy and nomenclature is an essential aspect of modern science. With an accumulation of the monumental amount of knowledge, scientists are required to specify and categorize each sub-field and every building block. Organization of knowledge also helps in the inventive process, because it assists in the visualization of the whole and highlights the gaps.

While analyzing the *Principia* for Newton's rhetorical purpose, I realized that it is paramount for a scientist to have a strong purpose. Although Newton's purpose of writing the book was to persuade his readers and Cartesian philosophers of his viewpoint, and convince them of his new way of doing natural philosophy, I learned that Newton was highly motivated to find God's workings. Newton was a deeply religious person and argued that the aim of natural philosophy should be to learn about the Creator or the Universal God by discovering the hidden laws that God has put into effect to run this universe. Thus, scientists and inventors should have strong purposes if they want to succeed in their investigations. Without a purpose, it is difficult to make progress because scientific investigations require immense patience and dedication. With the progress of our civilization and from our collective experience, we know that we can have another equally compelling purpose if we think about our fellow human beings besides the unknown God. When the rhetoric of science is taught to fledgling scientists, they should be encouraged to think for purposes beyond their personal gains; purposes that would help alleviate the sufferings of the poorest of the poor. Scientists with genuine purposes will be ready to avail of all available means of persuasion.

Through this analysis, I realized that scientists who discover or imagine theories know about the inherent complexities of their discoveries, but present their theories as simple laws and facts. Their interpreters and popularizers further present these laws and facts to the world in simplified terms. Newton knew that the orbitals were complex and that the theory of gravity was far from perfect, but he strongly believed in his laws and forcefully tried to convince others. In the present-day world, if we think about scientific facts or discoveries, each one of them is immensely complex than it seems. For example, if we consider topics related to health science, even the simple flu is extremely complex and difficult to treat or contain. Similarly, while we have been waiting for the genome technology to provide us with cures to diseases, genes are found to act in an inordinately complex way similar to the planets of our solar system. Thus, if we are aware of the rhetoric behind some pertinent issues, we will not be misled into false hope. Knowing that the scientific theories are extremely complex, we will know not to rely on them entirely; rather, we can make our own modest plans to solve our everyday problems on smaller scales. Such smaller solutions will ultimately have a cumulative effect in bringing desired results and would be highly expedient than the big solutions provided by the scientific theories, which are usually accompanied by bigger repercussions.

Newton shows yet another way of solving problems. We learn that he synthesized knowledge from different fields to construct his theories. This kind of synthesis combined with rhetoric is highly productive in finding solutions for problems that require knowledge from different fields. If the scientific world begins to stress less on specialization and encourage more cross-discipline studies, the world would become a better place. Such cross-cultural studies would certainly benefit from the study and application of the rhetoric of science.

We cannot deny that scientific rhetoric has been hugely successful in some respects while it has pathetically failed in others. Since the glorification of science, many scientists have achieved cult statuses for their discoveries. Science has made enormous progress riding on the appeals to *ethos*, *logos*, and objectivity, and the modern world is exploding with scientific knowledge. But it does not mean that science has ameliorated human living conditions everywhere. The use of science and technology solves many problems but creates an equal number of complications. Thus, whereas scientific rhetoric has been successful in creating enormous amounts of knowledge, it has failed monumentally in persuading people to use that knowledge in a conscientious manner. The world is teeming with hunger, diseases, terrorism, environmental degradation, and such. Therefore, we require the rhetoric of science, not just for inventive purposes, but also more importantly for the proper use of our collective knowledge and intelligence.

Thus, rhetorical analyses of scientific texts help us understand science as a subject and its relationship with the other fields of knowledge. Such analysis brings forth new insights and ideas. Studies in the rhetoric of science might help the development of science for the betterment of humanity because it will make scientists and lay people adept at using rhetoric to counteract the claims of people practicing pseudoscience or science for their personal gains. The rhetoric of science can be used in debates pertaining to public policies as well as to debunk false claims made by invested authorities. Despite the studies conducted in the field of rhetoric of science, we still have many flaws and gaps in the existing scholarship. Teaching and learning the rhetoric of science can develop the discipline and further help dispel many myths, increase awareness, and help people make informed decisions. Rhetoric should strive to sway the course of scientific investigations for the general welfare of the society. It would be beneficial for the entire humanity not just recognizing that science is a rhetorical construction, but stressing the fact that scientific rhetoric should include ethics as ethics is an essential part of rhetoric. Not only should scientists use all available means to persuade others, as Aristotle has famously advocated, but they should also follow his advice regarding practical wisdom (*phronesis*), virtue (*arete*), and goodwill (*eunoia*).

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