DEMONSTRATING SCIENTIFIC TASTE: AESTHETIC JUDGMENT, SCIENTIFIC ETHOS, AND NINETEENTH-CENTURY AMERICAN SCIENCE

A Dissertation
Submitted
to the Temple University Graduate Board

In Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

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August, 2012

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ABSTRACT

This dissertation explores how aesthetic claims in scientific arguments help construct scientific ethos through demonstrations of the rhetor's judgment. By examining the works of Josiah Willard Gibbs and Henry Rowland, two prominent nineteenth-century American scientists, through the lens of their formal rhetorical training as students in American universities, this dissertation investigates how aesthetic judgment is enacted in scientific writing and explores the rhetorical history of the terms "simplicity," "brevity," "imagination," and "taste" and their use in scientific arguments. The aesthetic judgment that both scientists demonstrate in their written work reinforced an understanding of scientific ethos. By placing nineteenth-century scientific writing in contact with the rhetorical theories of the time, this dissertation explores the history of aesthetic judgment in rhetoric and its influence on conceptualizations of the faculty of taste. The dissertation illuminates the connections between rhetorical training and the ability to perform appropriate judgment when creating a reliable scientific ethos in writing. Constructing a scientific ethos in writing became increasingly important and complicated during the time of great institutional change in scientific research, which occurred during the second half of the nineteenth century in America. Scientists constructed scientific ethos through demonstrations of aesthetic judgment in order to respond to the exigencies of both institutional pressures and disciplinary expectations.

ACKNOWLEDGMENTS

I would first like to thank my dissertation committee—Eli Goldblatt, James Salazar, and Jordynn Jack. I would especially like to thank my chair Susan Wells for her constant support throughout my graduate career and generous comments on my work.

I would like to thank Lori Salem and the Temple University Writing Center for their support, Keith Gumery for his friendship, Christine Palumbo and my summer comrades for their company and good humor, Oliver Gaycken for his support early in my graduate career, Alan Braddock and the members of the Temple University Arts Reading Group for their comments on early drafts of chapters, Peter Logan and the Center for Humanities At Temple for a 2010-2011 Graduate Fellowship, and Ruth Ost and the Temple University Honors Program.

I also need to thank the librarians and special collections staff at Johns Hopkins University and Rensselaer Polytechnic Institute for locating documents and granting me access to archival material.

I want to thank my parents Christine and Joseph and my brothers Raphael and Antonio for putting up with academic speak at family gatherings.

For his many, many, many years of friendship and support, I would like especially to thank Dan Schank.

Finally, I want to thank Olivia Butler for her longstanding support and patience during this process—you put up with a lot. Thank you.

For Antonietta Cutrufello and Eleanor R. Callahan

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CHAPTER 1

INTRODUCTION: AESTHETIC AND SCIENTIFIC JUDGMENT

Scientific argument and aesthetic judgment are no strangers to each other, and sciences that deal with natural phenomena, such as the natural or biological sciences, use readily available objects when remarking upon beauty (as one example of aesthetic values). For instance, the symmetry of biological organisms is commonly believed by scientists to be a mark of aesthetic beauty in nature. The beautiful example is accessible to the specialist scientist, the non-specialist scientist, and the layperson (almost) equally and its aesthetic properties need no explanation. The more abstract sciences like physics and physical chemistry offer theories, notably less accessible than physical examples, for aesthetic analysis and appreciation. Yet, theoretical work is often discussed as an example of beauty in science; in lieu of readily observable phenomena or objects, scientists present theories as aesthetic objects to be judged as such by specialists, non-specialists, and laypeople alike.

In the theoretical sciences, aesthetic components support arguments; these components are presented as evidence of the value of doing work and, in some instances, evidence of successful work. Although a cogent argument can be made that the physical examples of beauty in the natural world are actually artificial and constructed objects (the symmetry of a perfectly bisected animal specimen or the striking image of a carefully selected, dyed and mounted cell for instance), these beautiful items in and of themselves are not necessarily offered as support for doing good science or for adopting a particular theory. Lacking a readily accessible physical world, beauty is not revealed by theoretical science; rather, beauty obtains within the work of theorizing and supports a perpetually continuing project to value the work as representing successful aesthetic choices of the scientific rhetor. The choices of the scientific rhetor, then, are part of the construction of aesthetically pleasing arguments.

Whether in a physical example or a written argument, beauty is constructed through scientific work, but in theoretical science, beauty is wholly the product of the rhetorical labor of constructing arguments and marshalling supporting evidence in support of a theory—this construction relies upon a demonstration of appropriate judgment on the part of the scientist. In science, useful arguments can be beautiful and beautiful arguments can be useful, but the true object of scrutiny is the scientific rhetor and his or her ethos. The ability to judge the relative aesthetic merits of a scientific argument authorizes the individual scientist's ethos by generating an appropriate field of discussion for this aspect of scientific practice; the individual's scientific judgment is enacted, in part, through aesthetic judgment performed within writing.

Performing aesthetic judgment as a component of scientific ethos was particularly important in nineteenth-century American scientific argument.[1] The increasingly diverse group of scientific researchers had to rely on written arguments more and more as their work became more complex and their audience became more geographically disbursed. The diversity in audience location and specialties placed greater pressure on scientists' rhetorical labor. The rhetorical work of nineteenth-century American physicists and physical chemists demonstrates the complex connection between aesthetics, scientific

[1] In his article "The Art of Rhetoric: Aesthetics and Rhetoric in the American Renaissance," Christopher Diller argues, "rhetoric provided the instrumental rationale, critical terms, and cultural prestige for discussions of art in the early American republic" (6).

argument, and scientific labor during a particularly noteworthy period in scientific history. The second half of the nineteenth century saw massive changes to how scientific practice was done, the organization of sponsoring institutions, and the modes of funding theoretical research in the United States. Theoretical researchers in nineteenth-century America greatly advanced science and technology, but this work would not have been so influential if it had not been disseminated to a large and geographically diffuse audience through the written word.

In particular, historians of science and scientists credit the work of Josiah Willard Gibbs and Henry Augustus Rowland with advancing scientific knowledge in physical chemistry and physics respectively. Both scientists were important researchers and prolific writers. Furthermore, the training and careers of both scientists exemplified the unique nature of scientific education in nineteenth-century America; Gibbs earned a PhD in Engineering and Rowland earned a degree in Civil Engineering. Each man then embarked on a career in the theoretical sciences. Gibbs created mathematical equations that describe the changes in phase states of matter as it shifts from a solid to a liquid to a gas. Rowland was influential as both the first Chair of Physics at Johns Hopkins University and as the maker of precision diffraction gratings used in spectrographic research. For Gibbs, “simplicity” and “brevity” were central to his concerns about presenting his theories that spoke to his relationship to the scientific establishment in the United States. For Rowland, “imagination” was a fundamentally important mental faculty that all physicists should possess in order to be successful in addressing the exigencies of error and accuracy in their work. In both example cases, scientific ethos is performed through demonstrating aesthetic judgment—a process that borrows terms and critical concepts directly from rhetoric.

Central to understanding Gibbs' and Rowland's concerns about the presentation of their theoretical and laboratory work is the rhetorical concept of taste. Taste was the primary faculty that all rhetors had to refine and demonstrate through aesthetic judgment in compositions. The aesthetic judgment that both scientists demonstrate and discuss in their written work reinforced a culture of scientific argumentation, which combined this particular type of aesthetic judgment with other aspects of successful scientific practice. Their theoretical and laboratory work was only part of their total scientific labor. They were also responsible for sharing their complex and abstract work with other scientists. Today, this may not seem like much of a struggle, but in the mid-1800s, there were not many trained physicists or chemists in the United States who had the disciplinary knowledge necessary to understand the intricacies of their work. Furthermore, there was no such thing as a fully formed, standardized scientific writing style to learn and use.[2] Instead, scientists like Gibbs and Rowland relied on their formal training in rhetoric and

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[2] In *Composition and the Rhetoric of Science: Engaging the Dominant Discourse*, Michael Zerbe explains that what constitutes modern scientific writing is an institutionalized misreading of the Ciceronian plain style (38-39). This explanation agrees with the historical progression of the scientific article as explicated by Alan Gross, Joseph Harmon, and Michael Reedy in *Communicating Science: The Scientific Article from the 17th Century to the Present*. They argue the increasingly international audience and specialization within scientific fields resulted in a highly formalized scientific article. In particular, they cite a 1909 U.S. Geological Survey pamphlet of "'suggestions to authors of paper' submitted for its publications" and the 1925 publication of *Preparation of Scientific and Technical Papers* as evidence of the institutionalization of the modern structure of the scientific article (161-162). Although the modern scientific article would seem to eschew any aesthetic qualities in favor of a formalized "plain style," nineteenth-century scientific writing was not as institutionalized and formalized and allowed for more variations in style.

composition, which they received during their undergraduate years, to persuade their audiences. These connections between formal rhetoric training and later scientific writing offer rhetoricians an understanding of how aesthetic qualities of arguments can enter into scientific arguments in a productive fashion while satisfying disciplinary expectations about the usefulness of the theory. Taste, that critical faculty in rhetoric, undergirds both scientists' understanding of their rhetorical labor.

This dissertation investigates how aesthetic judgment is enacted in scientific writing by exploring the rhetorical history of the terms "simplicity," "brevity," "imagination," and "taste" as they are used by Gibbs and Rowland in their scientific arguments. These descriptive and prescriptive terms found in rhetorical textbooks and scientific arguments suggest that there is a rhetorical approach that scientific rhetors must take when crafting scientific arguments with non-empirical concepts, which speak to audience interests and concerns that go beyond the scope of scientific claims. A theory is deemed aesthetically pleasing because it successfully matches expectations for presentation and argument, reflecting the extra-empirical values of a particular scientific community at a particular time. Agreement on aesthetic properties of an argument strongly suggests shared, communal values used to judge a theory's presentation and the ethos of a scientist. This dissertation takes from both the fields of philosophy and rhetoric to explore the connections between aesthetics and argumentation in nineteenth-century American scientific and rhetorical training, two fields whose epistemological imperatives dovetailed to inform a culture of scientific practice focused on the moral efficacy of the scientist as a researcher and a rhetor.

Exploring the links between the history of rhetoric and scientific argument in nineteenth-century America allows us to investigate an aspect of scientific argument that has not received much attention from rhetoricians. Philosophers of science have long sought to engage the apparent aesthetic components of scientific practice, and historians of science have produced exceptional work detailing the place of aesthetics within scientific practice. We can speculate that there seem to be two reasons for the lack of rhetorical scholarship within this area of scientific argumentation.[3] The first reason may be that a study of rhetorical practice explicitly addressing an aesthetic sensibility may support popular misconceptions about rhetorical practice as being ornamental. The second reason may be that scientific practitioners value truth over aesthetic qualities and any attempt to engage with scientific rhetors' predilection to reference or make use of aesthetic appeals is a reflection of idiosyncratic choices made by an individual rather than representative of larger movements within science rhetoric. Scientific ethos relies on a closely bound and often obscured function of aesthetic judgments in scientific arguments.

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[3]A few works on aesthetics and rhetoric have been produced by scholars. Besides Diller's article mentioned above, there have been several pieces investigating the function of aesthetics in rhetoric. For instance, Glenn Alexander Magee investigates the relationship between aesthetic criteria and truth claims in philosophical arguments in "Architectonic, Truth, and Rhetoric." In "From the Depths of Rhetoric: The Emergence of Aesthetics as a Discipline," John Poulakos argues that "a great deal of aesthetics of the eighteenth century is indebted to rhetoric" (335). He continues this argument by claiming that the aesthetic investigations of Immanuel Kant were, in part, born from rhetoric and the longstanding investigation into rhetorical beauty. Furthermore, although the art of rhetoric may not have been a major focus of philosophers, it did not disappear entirely from discussions of aesthetics (350). In "Communicative Implications of Kant's Aesthetic Theory," Thomas Hove explains how Kant's aesthetic theory contributes to an understanding of what Hove calls "communicative socialability" (104). By parsing the difference between the beautiful and the agreeable in Kant's theory, Hove explains how understanding community understandings of "the beautiful" allows scholars to explore the "socially integrative work" that aesthetics plays in communication (112).

In the nineteenth century, “scientific taste” was a concept used to appeal to a general understanding of scientific judgment. The formulation of scientific taste helped construct the scientific rhetor’s ethos by supporting an understanding of the rhetor’s powers of judgment. This appeal to judgment is similar to the role of objectivity as a marker of a scientist’s ethos in that it relates to both the consensual activity of scientists as a group and the labor of the individual scientist to demonstrate his or her judgment as an aspect of the individual’s character; the appeal does not directly reflect on the accuracy or truth of the statement. Rather, the scientist’s standing in the eyes of the audience is an important component of the weight a theoretical argument has (at least initially).

Many philosophers of science have concerned themselves with how aesthetic values relate to truth in scientific argumentation. Philosophers of science have been addressing this question at least since the time of William Whewell’s 1847 *Philosophy of the Inductive Sciences*, where he explored the relationship between simplicity, as an expression of beauty, and truth. Even Thomas Kuhn spends a few pages in his oft-cited *Structure of Scientific Revolutions* to address problem of aesthetics in scientific theories; he argues that aesthetic arguments can be powerful persuasive tools used in instances where a new paradigm is only marginally better than the old one at solving a specific set of problems (155). More recent philosophers like James McAllister argue that aesthetic components of theories only arise *after* the majority of practitioners have accepted a theory—a theory’s aesthetic components become pleasing through the process of normalizing the new model. In this way, he envisions aesthetics’ role in scientific practice as a post-adoption act of scientific argument. As compelling as each of these approaches can be for explaining the appearance of aesthetic concerns within scientific argument, each one ignores the power of rhetorical practice in constituting useful arguments that adhere to agreed upon aesthetic properties while at the same time speaking to the demands of scientific ethos, which would at times seem to be at odds with subjective aesthetic evaluation. The success of a theory within a field may wax or wane, but judging aesthetic worth seems to be a constant. This suggests that beauty (as a sign of aesthetic worth) is not a function of a stable truth but constructed and reconstructed again and again in scientific argumentative practice.

Drawing on the rhetoric of science, the history of rhetoric, philosophy of science, and the history of science to explore the concept of aesthetic judgment and its connections to scientific argument during the institutional and epistemological changes which occurred in nineteenth-century America science, allows us to enter into the nebulous region of argumentation that is created by continued use of aesthetic concepts in scientific arguments. Rhetoricians of science have traced the ways in which scientific writing has changed over time and has been influenced by and influenced cultural conceptions of the scientist.[4] Furthermore, historians of rhetoric and composition have

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[4] There have been several book-length projects that investigate the role of rhetoric in scientific argumentation in the nineteenth and early twentieth centuries. Charles Bazerman's *The Languages of Edison's Light* explores how the technologies that Thomas Edison presented to the world would not have been possible without the sharing of ideas between scientists, inventors, patent offices, and others. And this communicative process is central to understanding how these technologies came into being and widespread use. In her landmark book *Rhetorical Figures in Science*, Jeanne Fahnestock explores the "conceptual and inventive power" of different figures of speech (viii). In this detailed study, Fahnestock explains such key terms as *antithesis*, *incrementum* and *gradatio* and then explores through short case studies how these terms helped generate new ideas in research areas like biology and electricity in the eighteenth and nineteenth centuries. Finally, the newest entry into the ongoing investigation of rhetoric of science in the nineteenth century is James Wynn's *Evolution by the Numbers: The Origins of Mathematical Argument in Biology*. In this work, Wynn explores how scientists make

excavated a rich history of the teaching of rhetoric in nineteenth-century American universities focusing on the rhetoric textbooks used to disseminate the foundational ideas of the Scottish New Rhetoric to a wide audience of university students.[5] Scientists'

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arguments using mathematical models and how they argue about the presence of mathematics in scientific theories. In particular, Wynn explains that he relies on historical as well as textual analysis to explore these connections (9). Each of these entries into the scholarship on the rhetoric of science uses scientific arguments from the nineteenth century as useful examples in exploring the role of rhetoric in scientific argument. Each author does so not by claiming some special formulation of rhetoric during the century but by exploring the historical and contextual importance of specific formulations of arguments.

[5] Several scholars have focused on the effects of the Scottish New Rhetoric on nineteenth-century American rhetoric and composition teaching and learning. In *Rhetoric in American Colleges, 1850-1900*, Albert Kitzhaber explains that the American-produced rhetoric textbooks in the second half of the nineteenth century was based in the writers of Scottish New Rhetoric—Whately, Blair, and Campbell (59-60). Nan Johnson explores the role of formal rhetorical training in the in the nineteenth century in *Nineteenth-Century Rhetoric in North America* and explicitly claims that nineteenth-century American rhetoric was clearly founded on the Scottish New Rhetoric (19). Indeed, chapter two of the book is dedicated to tracing out the specific influence of Whately, Blair, and Campbell on the rhetorical training of American university students. Taking a different approach to the history of rhetoric in nineteenth-century America, Jean Ferguson Carr, Stephen L. Carr, and Lucille M. Schultz explore the various textbooks used during the period in *Archives of Instruction: Nineteenth-Century Rhetorics, Readers, and Composition Books in the United States*. In particular, they claim that their work studies all manner of rhetorical textbooks including ones that were widely circulated and reprinted throughout the century. Of particular note is their claim that the works by Whately, Blair, and Campbell were especially influential on scholars and teachers understanding of style and the influence of the faculties on writers (23). In *Rhetorical Education in America*, editors Cheryl Glenn, Margaret M. Lyday, and Wendy B. Sharper gather a variety of articles from scholars exploring the link between rhetorical education in nineteenth-century American and then current understandings of civic engagement. In his recent *Composition-Rhetoric: Backgrounds, Theory, and Pedagogy*, Robert Connors notes the popularity of the Scottish New Rhetoric textbooks for instruction in American universities, noting that American universities relied much more heavily on "book learning" than did the British schools (70-71). Thomas Miller explains in *The Evolution of College English: Literacy Studies from the Puritans to the Postmoderns* that "[t]he precepts of Blair, Campbell, and Whately were even more broadly disbursed by other popular textbook authors such as Samuel Newman, Henry Day, and a host of imitators" (114). Each of these scholars investigates broader and more inclusive issues of rhetoric

rhetorical work, an important aspect of performing science, created and supported conceptualizations of their theoretical work. Philosophers of science have spent time investigating the ways in scientific arguments rely on non-empirical values, or values that are not immediately measurable through the methodologies of scientific inquiry.[6] Historians of science have explored the specific exigencies that drove changes in scientific agency and ethos in the nineteenth century.[7] These seemingly disparate fields

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in the nineteenth-century, and, in doing so, each scholar finds it necessary to discuss the relationship of the Scottish New Rhetoric to the history of American rhetoric in the nineteenth century.

[6] Non-empirical values can be powerful elements of successful scientific arguments. In "Living in the Material World: On Realism and Experimental Practice," Andrew Pickering explores the function of coherence as a function of argumentation and not as a one-to-one relationship to natural phenomena. Alexander Rueger examines mimetic experiments of the eighteenth century in "Aesthetic Appreciation of Experiments: The Case of 18th-Century Mimetic Experiments." In this piece he attempts to account for unsuccessful experiments that were deemed aesthetically pleasing (49). In doing so, Rueger explores the limits of the correlation between aesthetic arguments and scientific truth. In "Direct and Indirect Roles for Values in Science," Kevin Elliott explores the role of nonepistemic values by looking at the effects of indirect values on scientific argumentation. In this article, he claims that indirect values do not determine the truth of a claim but do influence the "evidential standards for justifying a claim" (304). In "The Omniscienter: beauty and scientific understanding," Peter Kosso attempts to move the discussion away from the relationship of aesthetics and truth claims to a new investigation of the relationship between beauty and understanding. He argues that understanding comes from seeing connections between discreet ideas, and that aesthetic components of argument facilitate the recognition of these connections (40-41). Each of these philosophers point to a new way to think about the connection between the activity of scientific claim making and aesthetic worth in an argument that does highlights the functional aspect (instead of the ornamental) of aesthetic appreciation in scientific arguments.

[7] Several excellent history of science studies focus on how scientists in the nineteenth century understood conceptions of themselves in relation to their research. In particular, scientists in the nineteenth century were working through a reconciliation of the demands of objectivity of scientific inquiry with the inherent subjectivity of lived experience. In *Suffering for Science: Reason and Sacrifice in Modern America*, Rebecca Herzig explores two competing and complimentary strands of thought for the scientist—

offer a way to examine the construction of scientific ethos through a rhetoric of science based in a tradition of rhetoric interested in training the mind to be aware of the world and rethink and present that world through a trained aesthetic judgment. In the nineteenth-century, this work would have been best accomplished by university-level rhetoric courses; as such, the historical context of the individual scientist's training must be taken into account when analyzing their use of aesthetic concepts in their scientific writing.

Aesthetic judgments are more central to scientific argument than is commonly thought. At best, aesthetics is often figured as an element of a theory or an object of scientific study that already obtains within the object and not a function of rhetorical practice. A study of aesthetic judgment, as constructed through rhetorical taste, illuminates the complex ways that rhetorical practice in science relies on an ethos of judgment. This, in part, intervenes in philosophical discussions of aesthetics of science and demonstrate rhetoric's role in shaping the values of scientific argument. Aesthetic choice is a function of a crafted, constructed argument or contextualization of an object of scientific study. This construction is rhetorical in nature and, as such, is subject to a rhetorical analysis to determine the nature of its function within scientific arguments.

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the objective, cool and detached observer and the scientist who was forced by will, compulsion, or sacrifice in science, which was depicted as the "epitome of secular reason and liberal political thought" (ix-x). Lorraine Daston and Peter Galison have detailed the history of objectivity in their aptly named *Objectivity*, and Daston has spent much of her career investigating the connections between scientific practice and understandings of the scientific self in articles such as "Objectivity and the Escape from Perspective" (1999), "Fear and Loathing of the Imagination in Science" (2005), "Scientific Error and the Ethos of Belief" (2005), and "On Scientific Observation" (2008). Later in the dissertation, I will take up Daston's work. Suffice it to say, her work investigates the intersections of the limits of objectivity as a mode of knowing in the sciences and the presentation of the scientific self in practice.

This study triangulates the study of scientific argument through the fields of history, philosophy, and rhetoric in the hopes of explicating the role of rhetoric in the formulation of one of the more paradoxical elements of scientific arguments.

Many rhetoricians of science have studied the role of communities in science to explain how persuasion in scientific argument functions and the work of these rhetoricians may offer a way into the study of aesthetics in scientific argument. Summarizing the work of Lawrence Prelli, Michael Zerbe explains, “Scientists’ rhetorical choices depend in large part on value and propositions that are considered legitimate in science” (61-62). Philosophers of science and historians of science have argued that aesthetic values are part of a value system and larger cultural context in which scientific rhetors make choices. If scientific rhetors are persuaded by extra-empirical aesthetic components of arguments to trust the individual’s ethos, those components, on some level, must be rhetorical—they exist within argumentation and not in nature. This is especially true of the sciences that rely on theoretical arguments—like the earlier work in physical chemistry and physics in the nineteenth century.

In the nineteenth century, the epistemological-psychological philosophy of the Scottish New Rhetoric and the culture of the “moral economy” combine to a support a nascent scientific rhetoric. According to these philosophies, the coherence and internal stabilization of arguments obtain through rhetoric and reflect the qualities of thought of the individual rhetor. These aesthetic judgments offered responsive and useful ways of describing scientific labor in terms analogous to those used by the Scottish New Rhetoric for describing mental labor, as any university-trained individual would have recognized. Therefore, the history of scientific argument is bound up with the history of rhetoric. The nineteenth-century scientific writer relied upon the formal rhetorical training they received in college, which relied heavily on the New Rhetoric of the Scottish Enlightenment.

In the same way that the "plain style" advocated in the scientific style guides is found in the writing of modern scientists, the stylistic devices of the Scottish New Rhetoric can be located in the writing of nineteenth-century scientists. Nan Johnson argues, "Nineteenth-Century theorists defined an extensive, inclusive range for rhetorical arts by conflating epistemological and aesthetic rationales for public speaking, the composition of written discourse, and critical analysis" (*Nineteenth-Century* 16). The conflation of epistemological and aesthetic rationales lies at the heart of how rhetoric of science is central to understanding the aesthetics of science. Like Diller's argument that rhetoric offered its own aesthetic response during the Romantic era and was borrowed by a nascent literary criticism, the quickly changing fields of science borrowed terms and concepts from rhetorical practice to describe the writing activities that were so central to the establishment and continued progress within specific fields. The rhetorical arts of the nineteenth century found in textbooks are the foundation for the modern rhetoric of science.

The connection between formal rhetoric and scientific argumentation can be found in the works of Gibbs and Rowland. Josiah Willard Gibbs was a physical chemist whose work became influential in founding that area of study as well as helping make great strides in thermodynamics. Gibbs' theoretical writing was widely considered dense and incredibly difficult to follow, both on a mathematical and linguistic level. As an undergraduate he took rhetoric courses that used Whately's *Elements of Rhetoric*, a major

Scottish New Rhetoric textbook (Yale University). Henry Augustus Rowland was the first chair of the Physics Department at Johns Hopkins and was widely known for his unswerving allegiance to accuracy. During his undergraduate years at Rensselaer Polytechnic Institute, he was exposed to the George Payn Quackenbos' *Advanced Course of Composition and Rhetoric*, a widely used distillation of New Rhetoric philosophy and teaching (Rensselaer Polytechnic Institute). The work of both men has not previously been the subject of rhetorical analysis. Indeed, the only works on either have been historical in nature. Neither scientist was known for making direct claims as to the centrality of beauty within their work. Rather, their work is composed of qualities identified by other scientists and philosophers of science as aesthetically pleasing, and, thus, the works were constructed with an understanding of the value of demonstrating judgment through the choice of aesthetic values.

In Chapter 2, I discuss the centrality of taste to scientific ethos in nineteenth-century America by explicating the changes that occurred in the sciences and the rhetoric classroom in American universities during the nineteenth century. Prior discussions of aesthetics in scientific argument have focused on the ways in which aesthetic choices reflect long-held community beliefs. By focusing on taste and scientific ethos, I respond to the ways in which aesthetics in scientific argument has been discussed up to this point by showing the link between aesthetic judgment in the rhetoric classroom and its implications for scientific practice in a period that saw changes in the established ways of doing and presenting science. I argue that the rhetoric classroom's focus on the interior abilities of the student fostered the link between aesthetic judgment and professional ethos. The Scottish New Rhetoric, the foundation for much of the nineteenth-century

American rhetoric taught in universities, focused on taste as a useful faculty—it allowed the rhetor to perceive the world, analyze it, and reorder it into new arguments. This faculty, in turn, informs our understanding of the role of objectivity as a mode of scientific investigation during a period of changes in science education and information dissemination at the national level. The historical context of the rise of university science informs our understanding of the rhetorical value of aesthetic judgment as much as the changing ideas of objectivity inform our understanding of the importance of aesthetic value judgments in creating scientific ethos.

In Chapter 3, I investigate the ways in which Josiah Willard Gibbs used aspects of his rhetorical training when communicating his new and difficult to understand early work with a national and international audience that was not familiar with his field or his methodology. I focus on how Gibbs was overtly concerned with particular aspects of presentation—brevity, simplicity, and the use of metaphor in his work. The moments of meta-discourse in his scientific writings reveal an individual who was concerned with the aesthetic qualities of his work, but these aesthetic qualities are expressed in the language of the rhetoric classroom and not the language of the scientist. Furthermore, his articulated concerns allow us to contextualize the later evaluations of his work by noting the emphasis placed on coherence as a central component of scientific argument. Through this exploration, we begin to see the ways in which aesthetic judgments inform our understanding of scientific ethos during this period. Lacking a disciplinary community capable of understanding his work, Gibbs relied on alternative means to generate appropriate ethos in his articles. The overall reception of his theories and their value to the scientific community stress the organizational values expressed through simplicity and coherence, suggesting that valuing the faculty of judgment is as an important component for valuing Gibbs' work.

In Chapter 4, I discuss how a distinctly rhetorical understanding of imagination is useful for Henry Rowland's conceptualization of scientific ethos and for responding to the scientific topoi of error and accuracy in his own work. For Rowland, the creative and imaginative scientist was best suited to responding to the varied exigencies of modern scientific practice—large and ever-increasing amounts of data, increasingly accurate equipment, and a growing and professionalizing cadre of scientists and students. During a period of institutional change and growth, Rowland publicly expounded upon the necessity for the research scientist to be responsible to his own research and to the new contexts in which he found himself. Like his natural science predecessor, the nineteenth-century research scientist was responsible for delivering the accurate results of experimentation, and for Rowland, this was a sign of scientific ethos suitable for the changing nature of scientific research in the late nineteenth century. In his version of scientific ethos, Rowland sees imagination and an aesthetic response to the natural world as a flexible tool for generating responses to the exigencies of error and accuracy. These exigencies are the primary reasons for refining theoretical research work for Rowland, and, in his position as Chair of the Physics Department at Johns Hopkins, he was able to instill this value in generations of students. In his public speeches and his scientific publications, judgment, which is rooted in aesthetic values, is central to understanding the scientific ethos appropriate for a new era of theoretical work.

The readings and arguments this dissertation offers are the starting point for a more sustained exploration of aesthetic judgment and its relationship to scientific ethos.

Nineteenth-century American research science is a useful period to investigate because epistemological and institutional change placed increased demands on the producers of scientific knowledge to demonstrate scientific ethos within their work. New ways of knowing the world and new institutional settings required a scientific ethos that could both respond to disciplinary and institutional demands and also make scientific work legible to increasingly heterogeneous audiences. My contention that we can understand key aesthetic values expressed in the lectures and articles of these two scientists by examining the central rhetoric textbooks they read and used in their educational careers may seem like a novel approach to the question of aesthetics' role in scientific argument, but I believe this work opens up a space within a usually tightly bound and codified relationships between scientific writing and aesthetic values. Hidden within the suppositions and implications of scientific argument are aesthetic judgments. The rhetorical choices of Gibbs and Rowland respond to historically situated value judgments about the worth of both scientific labor and the labor of writing. It was through rhetorical labor that both scientists made their internal selves present in their public demonstrations of scientific ethos.

CHAPTER 2

RHETORIC, SCIENCE, AESTHETICS: VALUE JUDGMENTS IN SCIENTIFIC RHETORIC

> *[James] Clerk-Maxwell somewhere says it would be 'poor scientific taste' to choose the more complicated of two equally well-evidenced conceptions; and you will agree with him. Truth in science is what gives us the maximum possible sum of satisfactions, taste included, but consistency with previous truth and novel fact is always the most imperious claimant.*
>
> -William James, "Lecture 6: Pragmatism's Conception of Truth" in *Pragmatism: A New Name for Some Old Ways of Thinking*

Scientific Taste and Imagination

In "Lecture 6: Pragmatism's Conception of Truth" in *Pragmatism: A New Name for Some Old Ways of Thinking*, William James argues through example that "taste" is a component of the decision making process in scientific work, where true statements are made through the argumentative actions of verification and validation (77-78). Taste is not the most important component of theory choice for James, but it is, nevertheless, a factor when it comes to scientific argument. He quotes James Clerk-Maxwell, the renowned physicist, as having uttered the phrase "poor scientific taste" to suggest an ongoing connection between science and aesthetic preference. Indeed, the connection between taste, aesthetic properties of scientific work, and correctness or truthfulness seemed to have been a consistent topic of interest in the nineteenth century, and scientists often discussed their work in the context of how it fulfilled or failed to fulfill criteria for scientific aesthetics. The link between these seemingly disparate elements of scientific argumentation had been grounded in official philosophical treatises like William Whewell's work about the structure of scientific work and argumentation throughout the nineteenth century, and this suggests that, while the connection between science and aesthetics was not the central subject of scientific argumentation, aesthetics meant something more than stylistic ornamentation. Taste was the faculty by which the scientist could discern and judge appropriate aesthetic elements and presentations of a scientific argument. This faculty spoke to the importance of an ethos of scientific judgment.

In the nineteenth century, William Whewell formally linked together scientific communication and aesthetics in *Philosophy of the Inductive Sciences Founded Upon Their History* (1840); he argued that simplicity was a primary aesthetic criterion for successful and useful scientific theories.[8] In his recent "The Beauty of Symmetrical Design: The Alleged Epistemic Role of Aesthetic Value in Theoretical Science," Gregory Morgan cites Whewell's insistence on harmony and simplicity as proof that Whewell

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[8] See Menachem Fisch's *William Whewell: Philosopher of Science* for an in-depth discussion of Whewell's influence on scientific philosophy. Fisch explains that Whewell's highly influential career saw the scientist and philosopher spend twenty-five of his fifty-four years at Trinity College Cambridge in the Master's Lodge. He was also instrumental in founding the British Association for the Advancement of Sciences and served two terms as Vice Chancellor of Cambridge University in 1842 and 1856 (1). Although he was a prolific writer in a variety of subjects, Fisch argues that Whewell's *Philosophy* was a "landmark in the ongoing effort by philosophers to comet to terms with the foundations, aims, methods, and achievements of modern science" (2). In making the case for study of Whewell, Fisch cites archived correspondence between Whewell Charles Darwin, James Clerk Maxwell, Charles Lyell, and Charles Sanders Peirce as evidence for the influence Whewell had on nineteenth-century conceptualizations and philosophy of scientific practice (6-7). Furthermore, Whewell is of particular importance here because of his influence in the founding of the British Association for the Advancement of Science. In particular, his suggestion that the association restrict membership only to scientists who have published works through learned societies suggests, at least in the figure of this one influential man, that aesthetic criteria and authoritative discourse are intertwined. Above all, Whewell was concerned with delineating modes of authority in scientific discourse.

supported beauty as an a priori sign of truth. Whewell states: "In [true theories] all the additional suppositions tend to simplicity and harmony; the new suppositions resolve themselves into the old ones, or at least require only some easy modification of the hypothesis first assumed: the system becomes more coherent as it is further extended. … In false theories, the contrary is the case" (qtd. in Morgan 6). Although Whewell does not specifically discuss beauty within his book, "the general tenor of his great work suggests that he links coherence to harmony, progress, and beauty in science–an optimistic view not uncommon in the mid to late 19th century. And . . . it is no accident that 'beauty' is the last word of *Philosophy of the Inductive Sciences*" (Morgan 141). As Morgan argues, Whewell's influential book does not discuss beauty in the sciences explicitly, but his philosophy of science does take coherence as a sign of harmony and as central to theory choice.

Scientists have historically evaluated theories using the aesthetic preferences alluded to by Whewell. However, the philosophical weight that Whewell's explanation lent to the connection between formulations of arguments and their correlation with truth obscured the centrality of judgment to successful claim making. We can clearly see this in the statement made by James: taste is the critical faculty that makes the determination as to the aesthetic qualities of a scientific argument, and while this faculty is informed by disciplinary concerns, Whewell's and James' more general discussions suggest a universal understanding of its form and presentation. Whereas this universal understanding suggests some form of a priori connection between beauty and truth (or correctness) through the mechanisms of simplicity and harmony, I argue that an individual scientist's acceptance of the existence of a priori signs of truth like simplicity or harmony reflect the individual's allegiance to specific community aesthetic values and preferences rather than a theory's explanatory power. Proper demonstration of these values, in turn, demonstrated the rhetor's ability to judge and above all to correctly use appropriate forms of taste as signifiers of community membership. In short, the issue is one of ethos rather than of logos in scientific arguments where aesthetics and taste are concerned. Focusing on the construction of a rhetor's ethos allows us to understand the importance of aesthetic judgment in scientific argumentation as a historical phenomenon as well as a philosophical one.

A rhetor's ethos signifies an understanding of the relationship between the rhetor and the audience, and in rhetorical scholarship, it is widely considered an aspect of the trained character of the rhetor. In "Aristotle's Concept of *Ethos*," S. Michael Halloran argues against the notion that the composition classroom teaches only style and has nothing to do with the substance of discourse by highlighting the centrality of ethos to the making of successful arguments: "In its simplest form, *ethos* is what we might call the argument from authority . . . Of the three modes of appeal [ethos, pathos, and logos] Aristotle acknowledges *ethos* to be probably the most important" ("*Ethos*" 60). Halloran goes on to argue that ethos is important precisely because the rhetor must understand it so as to present himself to the audience in the most successful manner. This means that the rhetor is judged on his character *and* the "manifestations" of that character made apparent by choices made in the speech or text (Halloran, "*Ethos*" 60). The three ethical proofs that make up this action are *arête* (virtue and goodness), *phronesis* (practical skill and wisdom) and *eunoia* (goodwill towards the audience).[9] In particular, it is *phronesis* that, according to William M.A. Grimaldi, sets the rules of "rational control" and helps to foster "intentional habits" (152). The intentional habits of the rhetor represent his or her adoption of communal values, and ethos is constructed through these habits.

These habits, as Halloran explains, are "conventional rather than idiosyncratic" ("*Ethos*" 60). Although, ethos then speaks to the individual's control over his or her own presentation, it also represents communal, shared values as well. At the heart of ethos, then, is the replication and transmission of communal values. The ethical speaker has practiced and mastered their internal self and reoriented him or herself towards a particular communally valued virtue. Once one has the habit of a thing, his or her character (their scientific self) will possess that virtue.[10] The rhetor makes his or her ethos present through representations of the disciplinary conventions of research, and taste is a virtue of character that expresses the individual's adherence to these conventions; the rhetor must demonstrate taste in representations of research in order to construct his or her ethos for the audience.

This chapter traces the connections between the history of science and the history of rhetoric within the American university system to demonstrate the centrality of taste to an ethos of scientific, aesthetic judgment in the nineteenth century. Judgments about the

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[9] See the "Glossary of Technical Terms" in The Library of Liberal Arts translation of Aristotle's *Nicomachean Ethics* for a fuller description of their meanings.

[10] See Rebecca Herzig's *Suffering for Science: Reason and Sacrifice in Modern America*. See also Lorraine Daston's "The Moral Economy of Science" in *Constructing Knowledge in the History of Science* for a detailed history of the scientific self in nineteenth-century America.

perceptions of the world are central to scientific claim making.[11] In the nineteenth-century rhetorical classroom, students were taught rhetorical practices, which included how to make aesthetic judgments in the area of belles lettres, and students brought these aesthetic values out of the rhetorical classroom into other practices. As the century progressed, belles lettres and written composition became two separate areas of study, but many of the aesthetic interests of belles lettres remained central to the study of composition. Specifically, judgment and taste would remain central to becoming an effective writer. By refocusing on how aesthetic judgment entered into the world in non-artistic writing practices, rhetoricians can explore the topic of aesthetics in ways that are normally reserved for the philosophy of science.

This chapter will first explore the ways in which philosophy of science has articulated aesthetics in scientific practice as either ornamental or as reflecting disciplinary concerns; however, recent work in coherence and arrangement suggests that more universal understandings of aesthetics need to be explored. In the next section, I trace the history of taste as a critical faculty of judgment taught in nineteenth-century American universities as part of formal rhetorical training utilizing the Scottish New Rhetoric; this work will help illuminate the widespread understanding of taste as central to scientific judgment. The next section will briefly describe the changing state of scientific institutions in nineteenth-century America to create a context for understanding

[11] See Lorraine Daston's "On Scientific Observation." She argues that scientific observation becomes so ingrained in the expert's practice that he or she is "conscious of the product but not the process" of perception (Daston, "Observation" 101). Furthermore, she argues that historians of science have not studied the process of perception, and that these studies would entail looking at the psychology of perception, which "is conceived as structured and collective, on the analogy of language" (Daston, "Observation" 101).

the centrality of taste to scientific ethos in an era when the settings of scientific practice and presentation shifted from localized, amateur scientific societies to universities and national and international professionalized organizations. The last section of the chapter explores the changing importance of objectivity as a mode of practice and representation in the nineteenth century in order to draw connections between an ethos of tasteful judgment and objective judgment in the nineteenth century to suggest that these two supposedly opposing aspects of scientific ethos afford similar understandings of representing judgment in scientific argument.

Rhetorical practice and scientific practice underwent significant changes in the nineteenth century. The turn towards theoretical science and the reorganization of scientific practice in American universities altered the relationship between scientific research and writing. Similarly, the changing rhetorical education in American universities reflected a new direction and purpose for writing instruction. For scientists, rhetorical practice moved from public oratory to a more isolated and print based activity. Current scholarship on the history of nineteenth-century rhetoric shows how rhetorical education evolved during the century in response to the changing universities. Rhetorical training, too, became focused more on the usefulness of composition—ceding the territory of belles lettres to literary studies. In a similar fashion, the training of the "scientific self" involved a subordination of the subjective self to the modes of objectivity. Scientific language would adopt the usefulness of rhetoric and seek to reformulate style in service of objectivity, but the Scottish New Rhetoric had always constituted the usefulness of rhetoric through taste, and the useful language of scientific argumentation is no exception.

Style Versus Substance: The Philosophical Debate

Central to the study of aesthetics in scientific argument is its role in helping to make and sustain a scientifically acceptable argument. Some scholars in the philosophy of science argue that rhetorical aesthetics are ornamental in nature and appeal only to surface-level values that are historically contingent. Others argue that aesthetic properties like simplicity and cohesion are central to the cognitive act of making sense of the world, and their inclusion in an argument implies that values of judgment are central to demonstrating connections between ideas and data. I argue that demonstrating an ethos of scientific judgment of aesthetic elements is a central aspect of the rhetorical transaction of scientific argumentation; aesthetically pleasing arguments signal the rhetor's allegiance to extra-empirical communal values that, in turn, support the rhetor's authority to make claims by also demonstrating his or her ability to judge the world according to those extra-empirical values. The rhetor's ability to judge and communicate that judgment to his disciplinary audience is central to an understanding of how rhetorical aesthetics affects theory choice.

The Object of Aesthetics: Aesthetics and Stylistics

The philosophy of science has long occupied itself with the aesthetics of scientific thought.[12] However, the treatment of scientific aesthetics tends to be general rather than particular, and this tendency to generalize glosses over the importance of the particular training and circumstances of the individual rhetor. A general approach to the aesthetics

[12] For an overview of recent work in aesthetics of science, see James McAllister's aptly named "Recent Works on the Aesthetics of Science."

of scientific thought seems to focus on claims that can be generally applied across historical moments. James McAllister has devoted considerable time to explicating the importance of aesthetics to theory choice and coherence. In *Beauty and Revolution of Science*, McAllister explores the mechanisms by which theories are chosen by drawing on Thomas Kuhn's work in theory choice during revolutionary moments in science. In particular, McAllister grounds his argument in Kuhn's formulation of the process by which new data upsets a paradigm, causing a desire to rectify the data with a new paradigm; thus, theory choice is a rational act based on factual data (Kuhn 92-93). McAllister theorizes that the aesthetic appreciation of a theory does not reside within a theory, but is "projected into theories by individual scientists, scientific communities, and observers of science" a process that he calls "projectivism" (McAllister, *Beauty* 31). Basing his argument on projectivism, a concept he borrows from ethics, he explains that the experience of beauty within a theory or object is the result of projecting that value onto the theory or object studied. When an observer encounters an object in which he or she believes beauty to be present, they are experiencing their projection of beauty as located within the object, and, thus, argues McAllister, the observer believes that beauty resides within the object.

McAllister does not believe that aesthetic preference will spur revolutionary changes; rather, he sees aesthetic preference in theory choice as a conservative value reflecting widespread communal agreement—the opposite of Kuhn's formulation of the aesthetics in science (McAllister, *Beauty* 137-138). McAllister argues that a theory's aesthetic worth appears after the theory has been accepted. "[A] theory with a long track record of empirical success is likely to be seen as aesthetically pleasing, since its aesthetic properties will have acquired great weighting in its community's aesthetic canon" (McAllister, *Beauty* 83). On the other hand, Kuhn argues that aesthetic appreciation emerges during debates over theory choice before a new paradigm is widely accepted (155). For McAllister, a theory's aesthetic value does not argue for its newfound inclusion into a community's canon; rather, its longstanding inclusion in a particular canon supports arguments for the theory's aesthetic value. A scientific community's support of a theory means that there should be an eventual re-evaluation of the theory's aesthetic worth; this also argues for an understanding of the overt acknowledgement by scientific communities that theories have aesthetic value and allegiance to a particular theory is bound up with aesthetic conceptualizations of theories. McAllister's argument suggests that scientific communities are aware of the function of aesthetics in their choice and support of theories, and a scientific rhetor would be knowledgeable about this aspect of theory choice and include it in his or her representation of the new theory. This apparent tacit agreement suggests that aesthetic qualities of arguments are involved in the initial act of persuasion during theory choice and not just an affirmation of communal values after a theory has been adopted. Furthermore, this suggests that an ethos of scientific practice that includes an understanding of these often-implicit agreements about aesthetic values would be a part of constructing a trustworthy professional ethos.

McAllister, by way of Bertrand Russell, offers some introduction to rhetorical work in scientific argumentation. Through a brief discussion of style as it relates to accepted and novel ideas, McAllister claims, "readers are more disposed to attribute elegance to a statement of orthodox ideas than to a statement of novel ideas, since the literary style that each epoch regards as graceful is best suited to expressing that epoch's orthodoxy" (McAllister, *Beauty* 84). Like Kathryn Flannery in *The Emperor's New Clothes*, McAllister locates argumentative power within style (Flannery 3). Style is one tool for replicating the cultural and social institutions in power at the time, but it does not account for all of the powerful ways that aesthetic choice is intertwined with an ethos that supports a professional scientific practice.

Although his overarching model for how aesthetics functions during theory choice is useful, McAllister replicates a notion of rhetoric as mere ornament rather than rhetoric as constitutive and foundational to theory representation. In his defense of a culturally bounded and formulated aesthetic preference, McAllister conflates shifting cultural and social allegiances with that of "fashion," his word for the phenomenon. In doing so, he robs rhetorical work of its power to constitute arguments. For McAllister, the theories that scientists choose based on aesthetic preference are not constituted of anything; rather, they appear before the audience as fully-grown wholes. He relegates rhetoric to the notion of style, leaving it as an antiquated appendage to his argument. Style is the result of some vague choice in his estimation and does not seem to have a cultural history of its own that would affect theory choice.

Scientific Practice and Evaluation: Cohesion Through Arrangement

Scientific theories are arguments put forward to address a pressing exigence which can only be addressed through agreed upon representational systems. The exigence usually takes the form of an unanswered or poorly answered question or a natural phenomenon that needs explanation. Whatever the exigence, the scientific rhetor is tasked with crafting coherent arguments that can answer a question or explain a natural phenomenon. In order to craft this argument, the rhetor must adhere to discipline specific extra-empirical values that only have explanatory power because they have been deemed central to an argumentative practice. Aesthetic and non-aesthetic elements interact to produce an argument that both demonstrates the rhetor's understanding of representational systems and are recognizable by the audience as adhering to those systems. Aesthetic evaluation of the deployment of elements of the representation is part of determining the theories worth for understanding its response to the exigence. Regardless of the aesthetic qualities of the natural phenomena being studied, it is the aesthetic qualities of the argument that influence perceptions of the rhetor's ethos and the theory's explanatory power. The rhetor's adherence to and facility with the representational system is determined through judgments about the aesthetics of the theoretical argument. Ultimately, the rhetor's aesthetic judgment underscores how important consensus about extra-empirical values can be when making scientific claims.

An understanding of the concept of aesthetic judgment seems to stand at odds with the epistemic demands of post-Kantian objectivity, and yet, the mechanisms by which a scientist judges the aesthetic worth of a theory seems to be inherent in nineteenth-century rhetorical training and practices within educational communities. Some philosophers of science have rethought the connection between aesthetic choice and scientific practice as pointing towards the significance of cultural values in the cognition of the natural world. Scientific practice seeks to model the natural world, and thereby allows for aesthetic judgment of these models. Furthermore, the aesthetic components of these models are also useful markers for how successful the rhetor is in explaining the natural world by using the scientific concepts at hand.

Scientific rhetors generate ethos through the legitimate use of accepted scientific practices. Many of these practices are based on the concept of objectivity, and this concept would seem to preclude any consideration of aesthetic judgments during periods before a theory has been widely adopted. In "Objectivity: False Leads from T.S. Kuhn on the Role of The Aesthetic in Science," Joseph Margolis refutes much of McAlister's argument, arguing in favor of an understanding of aesthetics and objectivity when "there cannot possibly be any principled disjunction between objectivity of the sciences and objectivity of the arts" (200). Margolis suggests that Kuhn's use of the term aesthetic denotes a firmly understood difference between "the aesthetic" and the "non-aesthetic" (192). By this, he suggests that cultural values as expressed through argument in scientific practice rely upon culturally understood systems of representation. These systems have generally agreed upon arrangements, which practitioners and critics deem acceptable to a lesser or greater extent. Margolis calls this "consensual activity" and suggests that the "scientific" and the "aesthetic" rely on this consensus (200). The act of consensus building focuses on representing arguments about the world and the objects under study.

Discussions of aesthetic qualities of theories are also part of paradigmatic scientific activities that highlight the consensual nature of scientific knowledge production. Although McAllister finds the focus on the rhetor a secondary component of theory choice, this focus is constitutive of scientific argument. McAllister bases much of his argument on Kuhn's conceptualization of theory choice, but Kuhn also suggests that aesthetic values persuade scientists that a newer paradigm is preferable to an older one. For Kuhn, this is especially the case where a newer paradigm is only marginally different from an older one (155). Regardless, aesthetics are of primary concern during the formulation of theories and the arguments for adoption of theories in scientific practice, since, as Margolis suggests, it is a consensual activity operating within a sphere of language use that is not immediately connected to the objects under study. It is through the rhetorical practice of crafting cohesively arranged arguments that the rhetor can demonstrate an ethos of aesthetic judgment, a consensual activity, which reflects his or her ability to make claims.

Like Margolis, Judith Wechsler analyzes the consensual activities of scientific practice and aesthetic valuation. In her introduction to *On Aesthetics in Science*, she explains that if one believes science has a one to one relationship to reality and assumes it "to be synonymous with truth, then the idea of aesthetics in scientific judgment or cognition may seem capricious or marginal" (1). She goes on to argue that science is an attempt to approximate reality, and that this approximation gives science latitude to conceive of alternative hypotheses "subject to aesthetic factors" (1). Wechsler argues that aesthetic judgments "operate in the cognitive processes of arriving at the product [of science]" (3). Arguably, then, rhetorical practices are constituted to address these cognitive processes; these rhetorical practices are, in large part, the product of science. As products of science, all aspects of an argument can be judged according to extra-empirical values.

Peter Kosso attempts to address the role of these extra-empirical values in "The Omniscienter: beauty and scientific understanding." Kosso reverses the exploration of scientific activity away from an act of justification and towards the act of understanding, which uses extra-empirical values to make sense of the world. In his formulation, understanding in science results from coherence. Rhetoricians can enter this debate by highlighting the contingent nature of understanding. As Kosso explains, “To understand something is to recognize the links between it and other ideas” (40). Kosso goes on to further place aesthetic criteria at the center of an understanding of scientific activity. Although he approaches this problem through the lens of perception, we can view this problem as an issue of arrangement as well. “Recognition of a coherence among theoretical claims, and the ability to follow links in the coherent system, are the criteria of understanding” (41). Kosso charges the audience with the responsibility of following connections and then using those connections to create novel ideas. Creating and maintaining networks of information is a crucial part of scientific activity, and scientific rhetors have to consistently demonstrate the proper ethos of judgment while maintaining these information networks. The ability to judge a theory as beautiful or to proffer a beautiful theory does not justify the theory’s truthfulness; rather, it demonstrates the rhetor’s understanding of nature and is not a “criteria for justification” (Kosso 43). A properly arranged argument may not justify a truth claim, but the arrangement of elements in an argument can denote the rhetor’s understanding of a phenomenon. Any aesthetic pleasure that results does not take away from the truth claim; aesthetic elements of an argument are not a return to mere ornamentation in lieu of argument. It does, however, place aesthetic judgment as central to the process whereby truth claims are presented in a persuasive manner to an audience.

Scientific argumentation seeks to present coherent arguments to an audience. In doing so, it assembles elements of scientific practice unrelated to one another to create a stable coherent argument in support of a theory. In "Living in the Material World: On Realism and Experimental Practice," Andrew Pickering investigates the ways in which experimental practice is used to make sense of the world. In particular, he locates the action of experimental practice within a nexus of three activities supporting the primary goal of experimental labor. He argues the ultimate goal of coherence is the outcome of a successful series of experiments, and coherence is not the same as natural correspondence (279). For Pickering scientific practice aims at making the disparate elements of experiment work together to form a single analyzable situation that tells us something about the world. This analyzable situation is not the result of correspondence but of manipulation—of arrangement of elements.

Scientific argument is primarily an activity whereby coherence is created in an atmosphere of incoherence. In particular, Pickering identifies three elements of experimental practice that work together to form this analyzable situation:

> Three elements are conjoined in the production of any experimental fact: a *material procedure*, an *instrumental model*, and a *phenomenal model*. The first point to note is that, in a typical passage of experimental activity, there is *no* apparent relation between the three elements. Incoherence and uncertainty are the hallmarks of experiment, as reported in ethnographic studies of laboratory life. Material procedure, instrumental models, and phenomenal models hang together and reinforce one another. (276-277)

The model by which these three elements hang together Pickering calls "interactive stabilization." Each element relies on the other elements to remain part of the coherent whole within experimental practice, and in this way scientists work against incoherence in their practice and create coherence through the arrangement of elements that stabilize each other within the limitations of a theory.

Interactive stabilization is a useful model for thinking about how aesthetic terms work within the project of creating knowledge about the world. Logical argumentation is, in large part, about arranging materials—facts, theories, suppositions, etc—this process of arrangement is subject to the rules of rhetorical practice. Like elements of experiment, aesthetic preferences can be used to help generate coherence when crafting and presenting an argument. Scientists generate coherence by highlighting and creating relationships between elements of their argument—facts, theories, suppositions, etc. Arguments deemed elegant or beautiful do so by creating coherence through the arrangement of elements in a fashion that corresponds to culturally determined criteria of beauty. Pickering's interactive stabilization enables rhetoricians to formulate a model whereby aesthetics obtained through arrangement can obtain within scientific argumentation without violating realist notions of scientific activity.

Aesthetic judgments refer to qualities of arrangement and not a subjective means of approaching the act of rhetorical invention. Furthermore, these judgments are part of a larger consensual activity of scientific claim making, which seeks to generate coherent models of the world. The rhetor's arrangement of elements within the model must successfully highlight links between information, but it must also conform to other values that are connected to successful claim making. Although these values may be extra-empirical, they have significant persuasive and explanatory force within theoretical arguments. Therefore, scientific rhetors must be able to demonstrate their facility with these values within the context of their scientific arguments. Far from being secondary or "capricious" judgments, aesthetic judgments speak to the communal aspect of scientific argument. Adhering to extra-empirical values is one aspect of generating the good will of the scientific audience, and it is a major component of scientific argumentation during transitional periods of scientific practice.

Rhetoric of Science and the Scientific Rhetor

Current rhetorical scholarship counters McAllister's argument that style and aesthetics in general do not have much influence on theory choice. This work also extends the connection between cognition and scientific claim making. Recent work underscores the communal context of rhetorical transactions when debating scientific concepts.[13] Leah Ceccarelli argues, "the development of [scientific] knowledge is dependent on a complex interaction of cognitive and social factors" (169). In the nineteenth century, these complex interactions were further complicated by changing institutional formats, which, as evidenced by the example of Whewell's insistence on prior publications as a criteria for entry into the British Association for the Advancement of Science, were addressed by insisting on placing more and more weight on the value of

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[13] See Nathan Crick and Joseph Gabriel's "The Conduit Between Lifeworld and System: Habermas and the Rhetoric of Public Scientific Controversies." In this article, Crick and Gabriel argue that modern democracy increasingly requires that citizens weigh in on scientific controversies, and "[t]hese controversies . . . provide the situational grounds that make possible . . . the interaction among citizens, scientists, and legislators through rhetorical forums that feature the discursive interplay among epistemological concerns, aesthetic experience, moral valuations, and practical judgments" (201). Although their article discusses current scientific controversies such as the issues of CO_2 levels and the discourse between several expert and non-expert groups, their thesis resonates with my understanding that scientific argumentation is a rhetorical transaction, which necessitates several different modes of interaction among participants.

scientific writing and publication. Furthermore, the increasingly powerful role that objectivity played in standardizing experimental practice and scientific communication complicates a reading of aesthetics (rhetorical or otherwise) as more than a minor persuasive element of scientific argument. One would assume that aesthetic arguments would have become less central to scientific theories, but the Whewell example suggests that it remained central to the process. Unlike McAllister's evaluation of style's importance to argumentation, it plays a more central role because it speaks to a communal understanding of communicative relationships.[14]

Above all, aesthetics of science seems to have long had some very important connections to rhetorical study and practice. Recognition of this role has been particularly complicated due to scientific practice's longstanding relationship to objectivity and the antipathy to rhetoric's perceived allegiance to style over substance. However, scientific activity is a rhetorical transaction, and aesthetic elements of an argument are part of that transaction and have value and weight within a given scientific community. Furthermore, the values that are attributable to aesthetics in scientific argumentation are not ornamentation, but are central to addressing incommensurability between theories and for helping persuade in theory choice. These aesthetic values seem to be ahistorical, but a closer study of them reveals that they reflect cultural values. These values help us understand the function of aesthetics in scientific argumentation as

[14] See John Poulakos' "From the Depths of Rhetoric: The Emergence of Aesthetics as a Discipline." Poulakos argues that Kant's understanding of aesthetics emerged from a rhetorical understanding of the relationship between rhetor and audience (347). The common senses, which gives the individual access to standards of taste, drives the will to communicate the experience of beauty as a communal experience.

part of the rhetorical transaction but not as merely an artifact; instead, the aesthetic values of rhetorical transactions are often central to an historically contextualized understanding of the value of ethos in scientific judgment and argumentation.[15]

Scientific rhetors are situated within a nexus of activity that demands they navigate a complex path using rhetoric to both adhere to longstanding traditions and create new ways of knowing. In *The Rhetoric of Science*, Alan Gross argues, "progress of science may be viewed as a dialectical contest between the authority sedimented in the training of scientists, as authority reinforced by social sanctions, and the innovative initiatives without which no scientist will be rewarded" (13). Rhetorical labor for nineteenth-century scientists existed in this nexus of activity; each of these activities relied upon communicating their work using the full repertoire of rhetorical tools at their disposal—working to appeal to authoritative structures and formulating knew theories of knowledge within specialized fields. The nineteenth century, in particular, is known for radical changes in the shape and context of scientific practice, and the rhetorical

[15] See Walter Weimar's "Science as a Rhetorical Transaction: Toward a Nonjustification Conception of Rhetoric." He explains how theories are constituted of arguments that are not in and of themselves logical proofs. In doing so, he argues for a much more nuanced understanding of scientific practice as one that involves value judgments during the construction of arguments. Weimar argues, that concepts in traditional logic are based on Euclidian mathematics, which has clearly falsifiable statements, and "Logic became a separate entity when proof procedures were taken from geometry and applied as syllogisms of valid reasoning" (2). He goes on to argue that this concept of scientific argument ignores the pragmatic situation scientists find themselves in when arguing for a theory. Instead, Weimar explains that theories are "conceptual gestalts" and seek to offer explanations for "actual and *potential* data" (7). Weimar concludes that a conceptualization of rhetoric as the various ways that arguments are deployed to induce agreement with the aforementioned "conceptual gestalts" by recognizing the "intrinsic valuational . . . dimension inherent in all scientific activity" (13). For Weimar, value judgments obtain through rhetorical transactions, which themselves constitute the theories *and* arguments in support of theories.

interventions that scientists undertook to respond to the shifting contexts for their work reflect epistemological concerns as well as implicit acknowledgement of the "authority" Gross discusses.

A historically contextualized co-reading of rhetoric and scientific institutional histories in the nineteenth century helps us re-think longstanding debates about the place of aesthetics in scientific argumentation. It also helps rhetoricians of science to explore the effects of historical understandings of rhetorical aesthetics by adjudicating between the two competing understanding of the role of aesthetics in scientific practice and argumentation. Burgeoning understandings about scientific practice in the nineteenth century coupled with changes in the teaching of writing suggest a fertile ground for understanding rhetorical aesthetics in scientific argumentation.

Nineteenth-Century American Rhetorical Education and Aesthetic Sensibility in Composition

Taste was the critical judgment of aesthetic possibilities in nineteenth century rhetorical scholarship and teaching. It was the faculty responsible for regulating the rhetor's perception, analysis, synthesis, and re-presentation of the natural world. Placing taste at the center of an understanding of nineteenth-century American rhetorical teaching allows us to rethink the standard narrative of change in American rhetoric in the nineteenth century. Current histories of nineteenth-century American rhetoric stress that the rhetoric classroom moved from a largely oratorical rhetorical training, aimed at public demonstrations of intellectualism and style, to written composition, which focused on the useful aspect of communication and fostered a sense of internal dialogue.[16] In this version of nineteenth-century rhetorical history, the study of the stylistic elements of rhetoric, belles lettres, split off from formal training in rhetoric to become literary studies and the study of the "useful art" of writing was reconstituted in the early composition classroom. Although this history is factually correct and charts the very real structural changes in the teaching of rhetoric and composition, it tends to present a too-neat description of the history of taste and style in the nineteenth century. A new look at some of this scholarship with an eye for the place of taste demonstrates that it did not wholly disappear from the composition classroom. The changes in rhetorical training occurred in a complex environment that included both the classroom and the textbook, as sites of instruction, and through these mechanisms, taste continued to be a powerful faculty and critical term for understanding the rhetor.

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[16] See Kenneth Cmiel's *Democratic Eloquence: The Fight over Popular Speech in Nineteenth-Century America*. Members of the scientific community where working hard to articulate their goals to a variety of stakeholders important to their continued practice, whether in the university laboratory or in private enterprise. At heart of the debates over the importance of scientific research were also the concerns over whose perception of scientific practice would be valued and this perception was founded upon consideration of who was authorized to speak and what this public speech would look like. Cmiel argues that eloquence was a civic quality; the ability to deftly speak in the public arena was the ability to engage in a civic world where arguments were formed and decisions were made, but that entry into this world was a contested act (24). The use of technical language, scientific language, was a hotly contested aspect of newer modes of public discourse (Cmiel 60). If the public discourse over the inclusion of technical language was problematic, then the discussion about the future of the users of that language was also undecided. At the heart of the changes in the American education system was a concern about how to respond to the country's infatuation with new technology and modes of production. This response occurred in the sciences *and* in rhetorical training and practice. Cmiel argues, "Critics believed that the poor grammar was because Americans were addicted to innovation and were unruly—all due to the commercial values of American culture" (125).

The Eloquent and the Practical

While nineteenth-century American rhetoric courses made heavy use of Scottish New Rhetoric texts and their focus on the mental faculties, rhetoricians began to change their focus from the eloquent to the practical as the understanding of the place and value of public rhetoric changed from an oratorical culture to a written composition culture. This change was attended by newer rhetoric and composition textbooks, which, while still based on the Scottish New Rhetoric, began to approach rhetoric and composition as useful for a rising middle-class of technicians and engineers. The main texts in use until the 1870s were Hugh Blair's *Lectures on Rhetoric and Belles Lettres*, George Campbell's *Philosophy of Rhetoric*, and Richard Whately's *Elements of Rhetoric* (Kitzhaber 49-53). The central elements of the Scottish New Rhetoric—a focus on the faculties, the theoretical primacy of taste as a critical faculty, and the attention paid to the imagination and style as key elements of taste—would become the basis of literary scholarship, and composition-rhetoric would take the "useful" as its central focus. The brief narrative of change recounted above closely matches the known history of an increasingly accessible university system that would eventually become (in part) state supported through the Morrill Act of 1862.[17] For this history of rhetoric in nineteenth-century American universities, rhetorical training shifted towards the practical and shed many of its classical stylistic concerns as writing instructors sought to teach students who had not had

[17] See Edward Shils' "The Order of Learning in the United States: The Ascendency of the University" in *The Organization of Knowledge in Modern America, 1860-1920*. He argues that the state-operated universities formed through the Morrill Act focused on "improving" students through the dissemination of knowledge and were not concerned primarily with generating new knowledge (28).

the benefit of a classic, liberal education (Connors 325). While the concept of the civic individual had changed from the upper-class landowners to middle-class engineers, the impetus to train young men (and women) as citizens still remained.[18] However, this change was not smooth, quick, or consistent.[19]

Before the widespread implementation of the elective system in the1870s, all university students were exposed to the same material at the same time in a given class. Throughout the century, American university students were taught mental discipline through training of the different faculties of the mind—the will, the judgment, the imagination, etc. (Kitzhaber 2). These faculties of the mind constituted the basis of educational philosophy and theory about how best to train students to be civically minded and morally engaged with the world around them.[20] Memorization and recitation, too, were models for training the mind, and thereby creating effective citizens. These exercises were undertaken in an effort to address the "universal faculties rather than local abilities" of student rhetors (Carr, Carr, and Schulz 7). The universality of the Scottish

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[18] See Robert Connors' *Composition-Rhetoric: Backgrounds, Theory, and Pedagogy* Chapter 1 "Gender Influences: Composition-Rhetoric as Irenic Rhetoric." In this chapter, Connors argues that the inclusion of women in the university classroom influenced the decision in the field to move from raucous debates to more refined compositions (44-56).

[19] See Phil Dolph's "Taste and Philosophy of Rhetoric." Phil Dolph argues for an understanding of the New Rhetoric of Campbell as espousing an understanding of eloquence as an art that appeals to the beautiful and the useful equally (105).

[20] Kitzhaber goes on to note that by the 1870s, the faculty psychology, which had undergirded much of the educational theory in the first half of the century, was being replaced by newer ideas that focused on the individual and specialized education in the sciences and technology. In particular, he credits the growth of the elective system as a result of this movement (19).

New Rhetoric's focus on mental faculties and its combination of rhetorical practice and mental training underscored the centrality of aesthetic judgment to the making of the civic individual in the rhetoric classroom.

Competing ideas about the centrality of style and taste in rhetoric and its collegiate relative composition reveal that taste maintained its importance for both the literary criticism of the latter half of the nineteenth century and the composition of more "mundane" texts, such as descriptive and scientific writing. According to Winifred Bryan Horner in *Nineteenth-Century Scottish Rhetoric: The American Connection*:

> The concept of *taste*, which plays such a major role in the rhetorics of George Campbell and Hugh Blair, was a direct outgrowth of the Scottish philosophy. It was first introduced by Lord Shaftesbury, who avowed that human beings have 'a sense of order and proportion' about what they perceive. . . . All Scottish philosophers . . . considered *taste* an inborn quality that could and should be cultivated and that was necessary for the advancement of society. Beauty and good were often equated as linked virtues of human beings and of society. (30)

The link between beauty and good as virtues of individuals and society was central to the rhetorical training that students received from both the original Scottish texts and from their later synthesizers and imitators. Linking individuals and society through virtues had a long history in the rhetoric courses in American universities.[21] Judgment and taste

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[21] See Thomas P. Miller's *The Evolution of College English: Literacy Studies from the Puritans to the Postmoderns* where he explains that the history of universities in the early Republic were closely tied to the needs of the mercantile class: "Composition, rhetoric, and oratorical literature of the time were set out as a program of study that was closely related with studies of modern history, philosophy, politics, and science to creates a curriculum that was responsive to the needs of the broader public" (84). In particular, Miller argues, "The mercantile and manufacturing classes found much to value in the republican synthesis of public duties and private rights through courses in moral philosophy and rhetoric in emerging colleges" (84).

remained central throughout the nineteenth century, even as the formal study of taste was being replaced by practical writing skills.

In "From Rhetoric to Composition: The Teaching of Writing in America to 1900," S. Michael Halloran locates the shift in rhetorical training in the university in three fundamental changes: a new focus on belletristic writing; the rise of a new middle-class and professionalism; the creation and widespread dissemination of better writing technologies (161). These three factors merged and as the university was reforming, they fostered a new understanding of rhetoric. Scholars charged with teaching rhetoric classes were relegated to a secondary status to literary writing, while new technologies and modes of production fostered interest in technical matters among a new professional class who wanted access to education commensurate with its desires.[22] For Halloran, these changes influenced professionalism's ethos with its focus on the "specialist whose service to society took the form of applying arcane, scientifically-based knowledge" to everyday problems ("Rhetoric" 168). And as Halloran argues the change fused the work of rhetorical practice, long held to be oratorical, with scientific work. The specialization and professionalization of the sciences coincided with a similar change in the humanities. In particular, he argues that the new forms of rhetoric—having been divided into description, narration, exposition, and argumentation—were further divided from one another by the emphasis on exposition and argumentation in scientific and technological writing. He continues, "persuasion became a minor aspect of argumentation, serving

[22] See Thomas P. Miller's *The Evolution of College English: Literacy Studies from the Puritans to the Postmoderns* pgs. 112-120. He relates how the early nineteenth-century chairs of oratory and rhetoric steadily shifted their teaching and research focus from rhetoric to literary study.

only to supplement substantive appeals with some appeal to passion" (Halloran, "Rhetoric" 168). The decoupling of rhetoric from its oratorical history and belletristic elements led to a new formulation of writing as a silent, utilitarian practice which did not aim to persuade an audience but rather to report and reflect nature in scientific writing.

Although Halloran's work helps us understand the changes in the nineteenth-century composition classroom, he is too quick to see a divestment in the study of taste in the rhetoric classroom. Halloran's work suggests that the trajectory of rhetorical training for American students in the nineteenth century helped create the modern English department and decoupled the study of argumentation from discussions of style. In effect, there was a schism created between "literary and merely literate writing" between "beauty (or the beautiful) and utility (and the useful)" during the nineteenth century (White 23). Hayden White, like Halloran, understands this split as a function of a burgeoning middle-class, which needed to differentiate itself from the working class, but he too sees the split as absolute and locates the study of taste in the study of literature. He explains that the "ideology of aestheticism" is founded on the idea that a society needs literacy and not literature. Literary study was for the leisure class, who had time for such things, but literacy was necessary for the functioning of the factory and business (White 23). Ultimately, White argues that aestheticism was founded on a study of literary texts' poetic "expression of genius," and it eschewed what he calls the scientific study of language—rhetoric (31). White's understanding of the changes in rhetorical training suggests that the development of the composition classroom was linked to the continued refinement of scientific and technical writing. As the sciences professionalized, those who had to work in these new fields needed training in useful writing (literacy), and those who had leisure time could concentrate on the artistic merits of literary works. While this understanding the history of rhetoric suggests that the beautiful (literary) and the good (literacy) were divorced from one another, at least in so far as they reflect civic virtues, the split may not have been as large as these scholars suggest.

Nan Johnson charts a different course for nineteenth-century rhetorical training, claiming that it mixed epistemological and aesthetic rationales for public speaking, the composition of written discourse, and critical analysis (*Nineteenth-Century* 16). Instead of a bifurcated rhetorical practice, which limited literary study to a leisure class and mandated useful writing for workers, Johnson sees nineteenth-century rhetoric as a synthesis of Blair and Whatley resulting in an increased attention to the affective powers of rhetoric on the will and the mind (*Nineteenth-Century* 14). Nineteenth-century rhetoric may have concerned itself with the development of taste, as White argues, but Johnson firmly places this development within a more broadly described arena—one that encompasses more than the social elite's intellectual dilettantism. Johnson's version of nineteenth-century rhetorical practice places the belletristic tendencies of eighteenth-century Scottish New Rhetoric firmly within a sphere of civic action. Whereas White suggests that belletristic values became the concern of the idle rich, Johnson argues that these values continued to operate within the composition classroom even as that classroom began to more and more address the needs of an increasingly technical and industrialized world.

Furthermore, the recent work by Nan Johnson and Robert Connor suggests that nineteenth-century rhetoric, contrary to Halloran and White, was a multivocal affair. In particular, there were several positions on the value and function of taste in rhetoric.

Although the theories all stem from Blair's work, they give special attention to taste in their formulation of the critical function of rhetoric (Johnson, *Nineteenth-Century* 76). As Johnson explains, these popularly used rhetorics "echo Blair's account of the epistemological foundations of taste by defining the imagination and the understanding as its major operations and by presenting *taste* as a faculty that involved highly evolved emotional and intellectual senses" (*Nineteenth-Century* 77). Ultimately, Johnson demonstrates that taste had achieved a centrality to other disciplines besides literary criticism in the nineteenth century. Citing David J. Hill's *The Elements of Rhetoric and Composition* (1878), Johnson explains that taste was central to "critical sensibility" (*Nineteenth-Century* 81). In particular, Johnson points to Hill's claims that "rhetoric teaches us . . . to add to mere correctness and consistency such force and attractiveness as to make our thoughts clear and interesting to others" and that taste is an important element of this training (Johnson, *Nineteenth-Century* 81). In Hills' formulation of rhetorical training in the nineteenth century, attractiveness (i.e. style) is a central feature of intelligibility. It is the way in which written composition can be shaped by the writer to make their "thoughts clear" to an audience.

The necessity for the rhetor to demonstrate his or her judgment to an audience is probably the most important element of the continued inclusion of taste, style, and imagination in the theory of rhetoric throughout the nineteenth century. Scottish philosophy's focus on the civic virtues and the civically engaged rhetor undergirded this focus on taste and style. Rhetoric trained the mind through the acquisition of rhetorical skill, and, thus, argument was powerful because it engaged the mind through the content of the presentation *and* the "aesthetic appeal of the rhetorical form" (Johnson, *Nineteenth-Century* 230). These are the faculties of the rhetor and the elements of composition that help create powerful and useful texts. Rhetorical training in the nineteenth century was concerned with taste and the affective powers, because they were necessary faculties for persuading an audience of one's point. These faculties were of the utmost importance for those attempting to gain literacy in the nineteenth century.

White and Johnson's differing reads on the role of rhetoric and its relation to style in the nineteenth century suggest that nineteenth-century rhetoric was not a monolithic field, but, rather, it differed in its theories and ways of conceptualizing the student.[23] These differing modes of conceptualizing rhetoric alter our understanding of the hard split that Halloran sees happening in the nineteenth century. The tension between these competing modes of rhetorical training resulted in changes to both the purpose of teaching rhetoric and the modes its presentation to students.

The Role of Rhetoric Textbooks

The shift from oratorical rhetoric to written composition, which fostered much of the diversity in rhetorical training, also changed the texts in use and the focus of classroom practice, but it did not eradicate earlier aesthetic values associated with a rhetorical practice designed for civic engagement. The values of oratorical rhetoric were maintained in later composition classrooms, even as some rhetoricians assumed that these

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[23] See Robert Connors' *Composition-Rhetoric: Backgrounds, Theory, and Pedagogy* pgs. 6-9: Connors argues that during the nineteenth century, there were several theories of how best to teach rhetoric and the primary function of rhetorical training that were enacted throughout the country. In fact, the only constant that he sees in rhetorical training in this period was the "personal attention students got from faculty" (9).

values were assimilated into the study of literature.[24] Taste and the faculty psychology continued to inhabit the rhetoric classroom through stylistic imperatives taught in rhetoric textbooks, which contained competing theories of rhetorical practice and drew from the older Scottish commonsense philosophy and faculty psychology. Although American rhetoricians produced several textbooks in the latter half of the nineteenth century, they borrowed frequently from other sources. As Carr, Carr, and Schultz explain in their work *Archives of Instruction*, American-produced rhetoric textbooks often included theoretical elements originating in the texts of Blair, Campbell, or Whately. Nineteenth-century concepts of copyright and intellectual property were much more elastic than envisioned by current law. Indeed, Brainerd Kellogg explains in the introduction to *A Text-Book on Rhetoric*, “the sentences used in the work have been gleaned from many writers, and often have been manipulated to suit the author’s need, so that they are seldom credited to anyone, or enclosed with quotation marks” (6). This textbook written in 1880 and published in 1886 clearly explains that it draws from a variety of sources; Kellogg feels under no obligation to credit the previous writers, a common practice throughout the nineteenth century.

For instance, Hugh Blair’s text was a premier tool for teaching the role of taste in creating appropriate rhetoric and presentation in the first half of the century and a reliable touchstone for textbook writers and teachers throughout the second half of the nineteenth

[24] See Winifred Bryan Horner’s *Nineteenth-Century Scottish Rhetoric: The American Connection*. The split between oratorical and written rhetoric can be traced at least to the Scottish universities of the eighteenth century. Horner further explains, “Rhetoric took on a new form under the influence of the Scottish commonsense philosophy, and classical rhetoric was often delegated to that part of the course that dealt with oral delivery” (42).

century. Marie Hocmuth and Richard Murphy explain that nineteenth-century American rhetorical scholars often based their work in Blair's text, which focused on presentation. In particular, as Hocmuth and Murphy explain, these scholars cited Blair's reason for focusing on presentation: "To speak or write perspicuously and agreeably, with purity, with grace and strength, are attainments of the utmost consequence to all who propose, either by speech or writing, to address the public" (158). The qualities of the speaker and his speech are emphasized over the ends to which they will be used. Perspicuity, agreeableness, purity, grace, and strength need to be attained first; the quality of the rhetor must be addressed before the civic act of speech can commence.

Contrast Hocmuth and Murphy's understanding with Kellogg's explanation of the value of rhetoric in composition in the introduction to his book *A Text-book on Rhetoric*, and we see a shift in the perceived value of rhetorical training:

> [W]ere rhetoric to end with simply teaching the pupil how things should be done, its study would not be fruitless. Rhetoric bears its *full* fruit, however, only when, in addition to his, it leads the pupil to *do* as they should be done. Not rhetoric in the memory alone, enabling one to criticize, but rhetoric that has worked its way down into the tongue and into the fingers, enabling one to speak well and write well, is what the pupil needs. (18-19)

In this 1880 explanation of rhetorical training, Kellogg underscores the use value of rhetoric by moving the metaphorical action of rhetorical training from the mind to the tongue and the fingers. There are two different understandings of rhetorical and compositional practice: one maintains there was an allegiance to earlier modes of understanding the form, function, and focus of rhetoric, the other stresses the pupil's use of rhetoric as a way to address needs. Furthermore, these two brief examples suggest that the competing foci of rhetorical scholarship and teaching lingered during and after the bifurcation of rhetoric into literary and composition studies.

However, splitting rhetoric into the study of belles lettres and the study of useful language was not the same as divorcing aesthetics from both these newly constructed fields. In the texts used in the classroom, the oratorical nature of stylistic elements remained a central part of the competing theories of rhetoric. Indeed, Lois Agnew argues that Blair's rhetoric explicitly engages the larger context of community to address issues of subjective valuation of aesthetic elements of taste: "Blair's apparent confidence in the individual's natural understanding of communication is therefore moderated by his belief in the ongoing power of the community to shape its public discourse" (32). Agnew understands Blair as having identified taste as an element of useful argument.

This connection between taste and usefulness was crafted for a student audience aware of the cultural constraints upon them to be intelligible users of the language. Furthermore, rhetoric's prescriptive power, which defines taste, regulates the rhetor's subjective formulation of taste as well (Agnew 32). The rhetor must compose and present arguments within culturally prescribed boundaries. Rhetoric therefore trains the faculties of the individual in the dominant values of the culture. Furthermore, rhetoric also helps invent discourse that appeals to an audience. Blair instructs the rhetor to defer to the tastes of the community at large. The appeals to the faculties through the imagination so present in the foundational rhetorical texts of the nineteenth century now operate in a shifting space of practice guided by rhetoric's imperative to engage the audience in a mutually intelligible action that demonstrates the rhetor's ethos.

Demonstrating ethos in written composition was certainly different than demonstrating it in front of an audience, and this difference influenced the composition classroom. Connors argues that rhetorical training changed from a classical approach concerned primarily with "public events and opinions . . . to be investigated, amplified, arranged, and presented" to "a rhetorical praxis far more personal, private, intimate" (302). Connors' work charts a change from the classical to the romantic where "[t]he world of external nature comes more into rhetorical consideration as description becomes one end of rhetoric" (302). From this change, Connors sees the growth of personal narrative writing in composition classrooms at the end of the nineteenth century and the decline of formal Invention theory where the student is assumed to have a common stock of liberal arts knowledge to draw upon when writing themes on "Anger" or "Luxury" (302-303). In this change, the shift is from the public knowledge to the private knowledge of the writer, and that shift is represented by curricular innovations and codified assignments. This practical aspect of rhetorical training demonstrates the continuing ways that rhetorical training was central to a recognized college curriculum. The shift to the personal knowledge of the writer coincided with an increasingly fragmented educational experience, which supported the ever-growing professionalization movement. It also complicates an easy understanding of compositional practice. I argue that knowledge of the rhetor as an individual transformed into knowledge of the writer as a professional. In the post-liberal arts education institute with its separate departments representing distinct disciplines, the individual rhetor had to address heterogeneous audiences that had different disciplinary interests but a common liberal arts education.

Despite the turn away from a traditional liberal arts education, rhetoric still remained a central component of undergraduate education in the nineteenth century. Although the rhetorical classrooms turned towards more personal writing, students were still expected to address a public of professionals, which shared similar vocabularies and values. Gregory Clark and S. Michael Halloran, in "Transformations of Public Discourse in Nineteenth-Century America" argue that early forms of discourse in America were based on group consensus and as the nineteenth century continued this public consensus was fragmented as professional career paths became more distinct and more attenuated through special degree programs (5-6). William N. Denman notes the same argument in his "Rhetoric, the 'Citizen-Orator,' and the Revitalization of Civic Discourse in American Life" (4). Clark and Halloran recognize the same shift from neoclassical to individualist focus of rhetoric, they see the impetus for this change in the introduction of new technologies and industries, and Denman agrees with this assessment. Echoing Clark and Halloran, he cites Engineering, a field of study at Rensselaer Polytechnic Institute (RPI), as indicative of the atomization of the liberal arts education (5). Denman notes, however, that while Latin and Greek where eliminated from the curriculum at RPI, rhetoric was maintained, and he sees this as part of the effort to address the needs of the then growing American middle class (5). While these needs where often described as utilitarian in nature, rhetoricians approached their fulfillment using the reconstructed tools of an oratorical rhetoric.

Mental faculties like taste where maintained within the reconstituted rhetoric classroom through iterations found within rhetoric textbooks. Although Thomas Miller argues that as the century progressed taste was "deemphasized" in rhetoric textbooks

(114), Connors suggests that the elements of style, which demonstrate taste, became codified in rhetorical textbooks. Extending the term "static abstraction" from Kitzhaber's *Rhetoric in American Colleges, 1850-1900*, Connors explains that the term includes "any pseudo-heuristic listing of what linguists call 'derived nominals'—abstract adjective-based nouns—whose purpose is to define good structure in prose writing . . . terms like Unity, Variety, Precision, Energy, Clearness, Order, Economy, and so on" (270). Connors notes that these static abstractions originated in Blair's rhetoric and were included over time in newer rhetoric textbooks. They differ from sentence-level stylistic concerns because they can address holistic issues with the composition (Connors 270-71). These static abstractions had their roots in belletristic rhetoric's training of taste, but they were altered to address the new demands of a changing university student body. The changing version of taste demonstrates how aesthetic components of rhetorical theory were changed and subsumed within a more "useful" art of composition that arose to address the concerns teaching faculty had for the ever-growing "under-prepared" population that were beginning to attend universities.

The writing practices and aesthetic value judgments learned in these classrooms and with these textbooks surely influenced an understanding of the arrangement and presentation of arguments. As cohort after cohort of university students took rhetoric courses, they were also studying in the sciences. The value judgments of taste, which defined successful argumentative practice, also helped students to conceive of their scientific communication in similar terms. Just as Blair's belles lettres mutated into literary study, the same underlying principles and theories made their way into the composing habits and language of student writers throughout the great changes in American universities throughout the latter half of the nineteenth century.

While scientific writing adopted a useful professional ethos, the understanding of the professional uses of language ignores the competing rhetorical theories in the nineteenth-century American university. While there were significant developments in what is now considered current-traditional pedagogy, both Connors and Kitzhaber suggest that other versions of rhetorical theory were still being promulgated. Central to many of these theories was Blair's concept of taste and its centrality to understanding the relationship between the natural world, the rhetor, and the audience. Although rhetoric bifurcated into the two distinct academic pursuits of literary study and composition teaching, taste remained central to both fields. Focusing on taste illuminates the differing values that nineteenth-century rhetorical scholars placed on taste and demonstrate that nineteenth-century American rhetorical training responded to changing historical circumstances by adapting the Scottish New Rhetoric to a more "use value" oriented academic culture rather than relegate taste as a critical term to literary studies only.

Professionalization and Specialization in the Sciences

In nineteenth-century America, the same historical and cultural pressures that changed the field of rhetoric were also placing pressure on scientific practice. Historians of science often cite the nineteenth century as the major turning point in American scientific research and its sponsoring institutions. By the 1850s, American universities began to turn their attention to retaining some of their recent graduates as advanced students, and the schools began creating space for their research and teaching efforts.

However, it was not until well after the passing of the Morrill Act in 1862 that American science became well situated within the university, because land-grant institutions were primarily focused on teaching shared knowledge to students and not original research. Historians of science mark the founding of Johns Hopkins University in 1876, Clark University in 1887, and the University of Chicago in 1892 as important events heralding the new research agenda of American scientists (Shils 28). Prior to these universities, local and national scientific societies were premier places for sharing scientific research. By the end of the century, the country had invested massive amounts of private and public funds into both research institutions and private companies.

The increased funding and attendant professionalization of scientific practice stood in stark contrast to the way that scientific investigation was treated earlier in the century.[25] In "Inventing the American Research University: Nineteenth-Century American Science and the New Middle Class," Dannette Paul and Ann M. Blakeslee argue that prior to the mid-nineteenth century universities did little to support the activities of scientist. As a group, their work was incompatible with the model of the university. Scientists acted more like hobbyists rather than professionals working under the auspices of a title and formal rules governing acceptable professional behavior (Paul and Blakeslee 242). They further explain that utility was the driving force behind

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[25] See George H. Daniels' *Science in American Society*. He argues that the employment possibilities for scientists were at a high mark by the 1880s. He reports: "by 1880 there were approximately 400 colleges and universities employing at least one scientist each . . . by 1882 there were 144 observatories in the country . . . [and] the possible establishment of a federal Department of Science, at the Cabinet level, was being discussed, and both state and federal governments were spending increasingly large sums on scientific research" (265).

American science in the nineteenth century, and because of this it was born of the middle-class problems faced by the young nation (Paul and Blakeslee 249). Both historians of science and rhetoricians cite technological changes and the growing need for engineers and other technical workers in the nation as primary drivers of the change in the focus on the sciences and their support in the university.

However, the changes charted by many historians of science also suggest a more complicated understanding of the history of scientific institutions in nineteenth-century America where institutional settings were in flux and universities were developing their individual missions, values, and contexts for scientific labor.[26] Mary Jo Nye explains that by the 1880s, university science faculty required separate facilities, solidifying the division of the “humanities” and the “sciences” and creating a separate “epistemological space” as well (xvi). A re-envisioning of nineteenth-century American scientific institutions allows rhetoricians to rethink of the role of rhetorical training in the university as connected to an increasingly specialized structure for scientific research and teaching. Some scholars have pointed to an ongoing connection to the more traditional liberal arts fields and the newer specialized scientific fields. Many of the young scientists trained in German universities in the mid-1800s had been exposed to scientific researchers who were also widely read in literature and philosophy and adopted and maintained the same polymath interests throughout their careers in the states (Shils 33).

[26] See Todd Timmons’ *Science and Technology in Nineteenth-Century America*. Citing the leading nineteenth-century American scientist Joseph Henry, Timmons explains that while scientists had gained more of a presence in American universities, it would not be until the twentieth century that scientists solidified their position in both research and teaching in the university (188).

The presence of these interests run counter to the narrative of straightforward institutional change and suggests that older liberal arts concepts would still find their way into scientific argument. Although there was an influx into the university of previously working-class students whose aims were to gain an education that would prepare them for a technical career, some of the driving force behind the creation of new universities and reorganization of older universities was still firmly rooted in earlier liberal arts educational theory. As scientific research was reorganized within American universities, it was also still being pursued in the older local science societies that dotted the nation and in the newer national professional organizations such as the American Association for the Advancement of Science. So, while it is tempting to focus only on the changes in the university as the primary context for scientific labor, it is important to remember these societies as well when considering the various institutional settings for scientific practice and presentation. Nineteenth-century American scientific institutions were more varied in form and function than often conceived.

The diverse institutional settings point towards the need to think about a more universal audience for scientific work. David Cahan argues that individual scientists did not know each other personally and were an "imagined community" sharing values that transcended disciplinary boundaries (325). These shared values began to be expressed through national bodies of researchers, which codified the inchoate values into publication and membership criteria. A shared sense of scientific ethos maintained through methods of scientific practice and modes of representation accommodated the fluid state of institutional contexts. The ethos of the professional scientist was being rethought within this matrix of professional activity, but the march towards professionalization did not eradicate older understandings of liberal arts education or training; instead, this understanding was modified and adapted to the changing institutions and practices.[27] The imagined community of scientists was nurtured and maintained through this matrix of professionalization through the mechanisms of lab and field reports, articles, and lectures.

The Changing University in Nineteenth-Century America

The Johns Hopkins University exemplified the major changes in scientific institutions of higher learning in the nineteenth century. Its opening in 1876 marked the beginning of the era of research universities in the United States, and members of the institution worked tirelessly to find the most competent research faculty for its science departments. Although the opening of major research institutions marked the new direction in American scientific research, shades of its past liberal arts tradition remained in the conceptualization of the university and its relationship to scientific research. In his inaugural address for Johns Hopkins University, Daniel Coit Gilman explains the reasoning behind the research focus of the university:[28]

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[27] John Higham coined the term "matrix of specialization" in the article of the same name. In borrowing the concept of matrix here, I point to the web of activity that occurred within the United States to imbue scientific activity with the power of what Higham calls the "technical elite." Further, he argues that the turn towards specialization "inevitability" fought against the democratizing aspects of the rise of the middle-class. He cites the consistent calls for "a higher order of things" that marked a turn against egalitarian views on newfound social equality among the classes (9). Higham's argument suggests that the turn towards the sciences and the more useful writing forms were not a completely untroubled project for American universities.

[28] See D.G. Hart's "The Protestant Enlightenment Revisited: Daniel Coit Gilman and the Academic Reforms of the Modern American University." Hart argues that the

> The object of the university is to develop character—to make men. It misses its aim if it produces learned pedants, or simple artisans, or cunning sophists, or pretentious practitioners. Its purport is not so much to impart knowledge to pupils, as to whet the appetite, exhibit methods, develop powers, strengthen judgment, and invigorate the intellectual and moral forces. It should prepare for the service of society a class of students who will be wise, thoughtful, and progressive guides in whatever department of work or thought they may be engaged. ("Beginning" 19-20)

University presidents like Gilman also affected the hiring decisions of department members. Indeed, Gilman was noted for handpicking his first faculty hires at Johns Hopkins. Much like his philosophy of the purpose of the university, Gilman's thinking behind his faculty choices reflected a commitment to liberal arts ideals. A little later in this lengthy address, he describes his choice of younger, lesser-known professors to staff the new university:

> I wrote, not long ago, to an eminent physicist, presenting this problem. "We cannot have a great university without great professors; we cannot have great professors till we a great university: help us in the dilemma." Let me tell his answer. "Your difficulty," he says, "applies only to old men who are great: these you can rarely move; but the young men of genius, talent, learning, and promise, you can draw. They should be your strength."

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view that the rise of the research university was a sign of "religious decline" in American university life is highly debatable and, in fact, that examples like Gilman demonstrate that earlier religious and moral philosophical concerns were made present in the research university through the men who shaped their focus (684-685). During his life, he oversaw the opening of the Sheffield School at Yale, where Josiah Willard Gibbs studied and then taught and where Henry Rowland briefly studied before returning to Rensselaer, and Gilman presided over the opening, staffing, and formative first years at Johns Hopkins University, where he handpicked Henry Rowland to become the first Chair of the Physics Department. Beyond the connections to this dissertation, Gilman was vocal about the need to adapt the modern university to prepare students for the new, industrialized world they would enter. Hart argues, "The modern American university's ties to the denominational college as revealed in the case of Gilman and Johns Hopkins University shows . . . that there was greater continuity between the . . . moral philosophy of the denominational college . . . and the new learning of the modern university than modern historians have allowed" (702).

> The young Americans of talent and promise—there is our strength, and a noble company they are! We shall not ask from what college, or what State, or what church they come; but what do they know, and what can they do, and what do they want to find out.
> (Gilman, "Beginning" 27-28)

Gilman's address illustrates the hopes for the new structure of American research institutions in the nineteenth century, and philosophical underpinnings of the earlier liberal arts structure. The university that Gilman envisions in his speech is oriented to its mission through a mixture of liberal arts tradition and professional coursework brought about by the growing demand for technically skilled middle-class workers in the country. Gilman reminds listeners that the purpose of the university is to "develop character," and he contextualizes the need for this development within the larger societal need for specialized work of the latter half of the nineteenth century. Johns Hopkins' mission was to prepare students for the future of civic and personal work in a professionalized world of specific, highly skilled technical tasks, and Gilman argues that having a highly qualified and engaged research and teaching faculty will directly support the university's work.

The relationship between teaching and research was also gaining attention in the university. Gilman takes what would have been first seen as a weakness—the inability to procure experienced faculty—and turns it into an asset of the fledgling university. A good professor must be a good researcher as well, and Gilman's address highlights this tension between the traditional purposes and methods of teaching and the new demands placed on colleges and universities to train young men to enable their success in the changing nation. Gilman also relates that his problem is finding great men who can move to teach at Johns Hopkins (some of the speech later on discusses the relative merits of moving to Baltimore), but the juxtaposition of the "old men" who cannot move and the young men of "talent" who will be asked to come no matter their college, state, or church suggests that he is more concerned with abstract motivations and commitments of the researchers rather than geographical difficulties in relocating them. To be sure, Gilman had some setbacks enticing professors to join the early Johns Hopkins' faculty.[29] However, his new vision for a university required faculty physically to change locations and metaphorically to move into new modes of research and teaching. He produced an image of a university that actively supported new modes of teaching and research and searched for new ideas from whatever quarter it could find so long as specific research interests were foremost in the researcher's and instructor's mind.

Gilman's address suggests that changes occurring in American universities affected what was taught as well as how it was taught. Redefining the purpose and place of higher education was a response to economic and technological changes and drove many of those changes later in the century. In "University Identity: The Teaching and Research Functions," Hugh Hawkins identifies one of the major challenges for the changing universities of the United States as the work of balancing research and instruction (286-287). This balance was fundamental to the reorganization of the American university, but in the absence of a formal, national plan university presidents and faculty were free to shape these programs to fit their understanding of the purpose of higher education. A generally agreed upon purpose for higher education in the latter half of the nineteenth century was the increased attention to teaching technical skills. Despite

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[29] See the history of Josiah Willard Gibbs in Chapter 3. Gibbs was offered a position at Johns Hopkins University, but declined, choosing instead to remain at Yale where he had previously been an unpaid professor.

sometimes-elitist intentions, universities had a democratizing effect through teaching much needed technical skills in an increasingly industrialized world. In order to so, they had to also become a force for scholarly excellence, which necessitated time and material support for research.

Although presidential inaugural addresses do not define the research and writing activities of scientists working in academic institutions, speeches like Gilman's suggest that the overall direction and tone of teaching and scholarship in these institutions was utilizing a value structure that harkened back to earlier faculty psychology theories. David Cahan argues that universities are one incarnation of the institutions that "facilitate the transfer of scientific knowledge, skills, and values from individual to individual and generation to generation" (293). Cahan goes on to explain, "[U.S.] graduate research institutions were in good measure built on the values and structures of their collegiate bases" (306). So, while Gilman and his colleagues desired to create a new nationally recognized institution that differed from the local college institution, they drew much of the structure and many of the values from what had come before. These values and structures are part of the shared make-up of the mid-to-late nineteenth-century research community. As with rhetorical training in the nineteenth-century American university, scientific practice and research changed over time within the American university, and the larger institutional community often had an effect on its shape.

Scientific Societies: Local and National

Prior to and during the changes in the American university in the mid-to-late nineteenth century, regional and national scientific societies operated as physical and conceptual spaces for research scientists. Before the introduction of the research university in the United States, scientists relied on European universities for their graduate training and regional institutions in America for a continuation of that research work upon their return. During the nineteenth century, scientific research became increasingly sophisticated and, due to the influence of American students returning from mainly German universities, it was increasingly being located within the university. Graduates of American universities could not continue their original studies within the country, so they increasingly made their way to Germany to study in schools with distinct departments specializing in scientific disciplines. Upon their return, these students became active in scientific research as independent scholars in local scientific societies. Institutionalized, original research in the United States took almost a century to organize itself as a recognized university practice. With the increased university support for specialized research came increased professionalization in the sciences. As a result, professional associations were created to foster communication among scientists in the newly constitute field and to create a shared identity among the practitioners. The sciences saw increased specialization and the formulation of new discourse communities within the specialties. Prior to the development of these specialized national bodies the local society was the premier place to share research.

The local scientific society was the premier model of scientific community and production in the United States during the first half of the nineteenth century. These organizations often drew their members from local individuals interested in natural philosophy. They were funded through the collection of dues and sometimes through the sales of publications. These institutions offered likeminded individuals an arena to share their research, and they sometimes offered (limited) facilities to produce research. The consistency and quality of these organizations' publications varied, but they were a central way for interested parties to share information. These societies had a long history in the United States, and were modeled on the Royal Society of London, and while they played an important role prior to the mid-nineteenth century, their regional membership and focus made them less central to the progress of scientific research in the United States as the second half of the nineteenth century progressed.[30]

The early regional societies were often made of interested men, many of whom lacked formal credentials from a university. Regardless, the scientific societies in America continued to perform the important service of exchanging information with each other and universities well into the second half of the century. In "Outposts of Science: The Knowledge Trade and the Expansion of Scientific Community in the Post-Civil War America," Daniel Goldstein explores the importance of scientific societies as "nodes" working to transmit information across physical and disciplinary distances. These scientific societies were increasingly common as the nineteenth century progressed, and while they did not necessarily offer the same critical apparatus available to European contemporaries, they did represent an effort to make public what had traditionally been a private activity of interested professors and hobbyists (Goldstein 523).

By the end of the Civil War, scientific societies would be an important part of the culture of scientific activity in the United States. They were responsible for transmitting information, through meetings and publications, to members. Above all, scientific

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[30] See Todd Timmons' *Science and Technology in Nineteenth-Century America* for a more detailed history of the regional scientific society in American history (176).

societies in the United States were a manifestation of the privileging of public displays of science over the private practice of individual researchers (Goldstein 528). The public nature of these scientific organizations was an effort to communicate the work of the scientist with the general public. It also highlights, as Goldstein accurately describes, a new effort to communicate research and findings between colleagues in different (and newly) specialized fields. However, these societies existed as a loose network sharing ideas, and they did not offer systematic training in the various scientific fields. In the latter half of the nineteenth century the national societies consisting of specialized professionals would help to solidify the relationships between specialized professionals working on university departments throughout the nation. Whereas the "outposts" described by Goldstein functioned as nodes of knowledge production, which transmitted information to each other, the national societies helped create a unified sense of the profession on par with the European societies.

The premier example of the national, professional society is the American Association for the Advancement of Science (AAAS). Its history demonstrates its flexibility in the face of changing expectations from both its members and the general public.[31] However, the primary goal at the outset of the organization was to create a national presence and place for scientists so as to raise the international stature of

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[31] See Sally Kohlstedt, Michael Sokal, and Bruce Lewenstein's *The Establishment of Science in America*. The authors explain, "Among the issues that they would confront were several that would recur throughout the association's ensuing 150 years: how to maintain an open yet focused forum for scientists to exchange information about their research; how to foster communication among disparate scientific areas of study, and outlook that might today be identified as interdisciplinarity; and how to embody the principles of democracy and popular access while advancing scientific knowledge that seemed increasingly esoteric to many people" (8).

American science (Kohlstedt et al 9).[32] Through the nineteenth century, the society grew and formalized its membership practices and faced new challenges as successive presidents and membership communities continued to refine the society's form and function within the larger American culture. To do so, the AAAS raised entry standards in the early 1850s into the society, so as to further distance their membership from the American public's perception of American scientists as charlatans (Kohlstedt et al 13-14). As the second half of the nineteenth century progressed, there was increasing pressure from the public and from members to invest society money in public endeavors, such as the coastal survey of 1885 (Kohlstedt et al 38). All of this activity illustrates the internal changes that a large organization like the AAAS underwent in the nineteenth century as it defined its mission and its membership by new criteria for scientific professionalism.

The growing need for scientists to explicate values that could ground disparate research practices and institutions is exemplified in the changing institutions of scientific research and community development. These institutions and professional organizations needed to establish their credibility within specific disciplinary fields, and it was important to do so in a public fashion that would signal to the larger community of scientists and the nation that members of the group could be trusted. Indeed, Joseph Henry, the second president of the AAAS, stressed values and laws of practice across the sciences rather than the discrete fields of knowledge each branch represented (Lucier

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[32] See Paul Lucier's "The Professional and the Scientist in Nineteenth-Century America." Citing the third president of the AAAS Alexander Dallas Vache, Lucier explains that the organization was created to "cultivate" scientific enterprise in the United States, and that although its membership was relatively open, the officers of the organization worked to fulfill this duty (708).

708). The move towards standardizing values across disciplines was an attempt to promote specific national societies and to articulate professional values that would guide an individual's practice.

Scientific Publications

As the example of AAAS publication controversy in the early 1850s demonstrates, publication standards reinforced standards for knowledge production and community membership. The imagined community of scientists existed mainly through the printed journals, which had become increasingly important to the maintenance of scientific communities throughout the nineteenth century. Publication had long been a criterion for entry into the British Association for the Advancement of Science, and the AAAS adopted a similar method to determine its membership in the 1850s.[33] Membership in a national body of scientists was reliant on publication credentials, and this in turn supported a changing understanding of the scientific community's make up. As we see with the creation of graduate scientific schools and the formation of organizations constituted by professional scientists whose audience for publication are professionals and policy makers, the second half of the nineteenth century saw a very different type of scientific activity, which aimed to manipulate and theorize the factual data collected through the eighteenth and beginning of the nineteenth centuries. Howard

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[33] See Alan Gross, Joseph Harmon, and Michael Reidy's *Communicating Science: The Scientific Article from the 17th Century to the Present*. The authors explain that in 1831 William Whewell proposed that membership to the British Association for the Advancement of Science be restricted only to individuals who had published "written papers" through a learned society (117).

Miller explains in *Dollars for Research: Science and Its Patrons in Nineteenth-Century America* that scientific knowledge, as factual data, had become overwhelming for the vast majority of scientists by the 1840s (7). The sheer amount of data produced by their combined research was outstripping their ability to theorize its significance, and publications became a means for simultaneously sharing new data and theories and for solidifying the identity of the professional scientist. This activity was uniquely rhetorical, and the changing nature of rhetoric in the university, reflected in public discussions about "useful language" illuminates the role of language in scientific argumentation during this period.

The written document was central to the changing institutions and their mission of professionalization.[34] It was also the primary way that scientists maintained contact with the imagined community of scientists as well. Like European scientific publications in the 1800s, American publications were an important way to disseminate new theories. *The American Journal of Science* exemplified the strong connection between institutions and print publications. According to Gilman in his 1901 address "The Relation of Yale to Science and Letters," these two "agencies" were central to the "second era" of Yale as it transformed from a regional college to a leading research university (184). The connection between the different institutions of scientific knowledge making suggest a slightly more nuanced review is in order.

[34] See Peter Dear's "Narratives, Anecdotes, and Experiments: Turning Experience into Science in the Seventeenth Century" in *The Literary Structure of Scientific Argument* ed. Peter Dear. Dear argues, "An account of an experiment . . . is a piece of social currency" (137). In the nineteenth century, technological change was bound with discursive practices made concrete in written documents. In *The Languages of Edison's Light*, Charles Bazerman argues that as practices grow more complex so do discursive practices (335-336).

Increased specialization and differentiation in scientific institutions suggests that the increasing reliance on argument would tend towards a rational and objective mode of research and presentation; different fields constituted knowledge using different methodologies, so there was a need to standardize some aspects of all disciplinary practice. Scientific writing was the mechanism by which the different fields of research produced work that was still legible to non-disciplinary audiences; scientific writing would need to be able to function across institutions so that knowledge could be constructed through a text-based social practice. The discourse community of scientists was becoming a geographically diverse group of individuals who had various institutional and disciplinary commitments, but it needed to still maintain community standards across these physical and institutional divides.

Alan Gross, Joseph Harmon, and Michael Reidy's recent study of the scientific article suggests there is a link between modes of scientific writing and the continued, dynamic process of professionalization.[35] Although the process of professionalization that Gross et al describe occurred within Europe, it is applicable to America as well. Gross et al argue, using Olbrechts-Tyteca's formulation of the implied audience, that nineteenth-century scientific audiences were comprised of "scientists per se; as those interested more in pure science, or more in its applications; as professionals within a specific discipline, or anyone with a general interest in science" (119). Although scientific knowledge became more complicated and more abstract, it was the organizing

[35] The authors make it clear that they find professionalization a decades long and dynamic process whereby practices are normalized. In particular, they cite Helge Kragh who argues: "professionalization is inherently dynamical. It is a process, not a state" (qtd. in Gross et al 118).

structures of the institutions that fostered such a diverse implied audience in the first place. Scientific argumentation was a response to institutional as well as professionalizing influences, but it also supported these activities.

Changing Institutions and Flexible Scientific Ethos

The changing nature of scientific practice in the nineteenth century was evident in the new values expressed by members of research institutions, and addressing this change involved invoking a new ethos of scientific teaching. In his speech commemorating the opening of the Hale Scientific Building at the University of Colorado in 1895, Henry Carhart proclaimed:

> On the occasion of the formal dedication of a building devoted to the teaching of science, it is fitting that something should be said respecting the claims of science to such generous recognition and such ample provision for its cultivation in a young university, established by a Commonwealth itself still 'in its teens.' In the Atlantic States the stagecoach is almost obsolete. It has given way to the railway, and it is an open question whether transportation by steam will not ultimately yield to the agile trolley wheel. So the old-time college, devoted to the ancient languages, mathematics, and little leaven of moral philosophy, with its slow-going ways, its simple outfit of benches, a teacher's desk and a chapel, has been superseded by the modern university, with its complex organization, its multiplicity of courses and subjects of study, its laboratories and equipment, and its corps of trained, eager, alert instructors, who are not expected to teach a book only, but to add to the sum of human knowledge, and to awaken in kindred spirits at least an enthusiasm for study, a delight in investigation, which has proved the most efficient stimulus to high intellectual attainments. (393)

By the end of the century, Carhart’s description of the modern university seemed to accurately reflect the new form of the learning environment. Carhart charts the changes of the American university through the progress of technology, and he dismisses the liberal arts tradition exemplified by the sparsely equipped one-room lecture hall. Carhart envisions the modern university as possessing a “corps of eager instructors,” who are also accomplished researchers “adding to the sum of human knowledge.” In his description of the older university, there aren’t any instructors at all. By equating the instructor with the simple classroom and materials, he erases their presence all together. The only professor worth discussing is the one who does research, who engages in the practice of scientists and inspires his students to do the same.

In this example, what seems to be a paean to the modern university as constituted in the late nineteenth century actually demonstrates many of the concepts discussed in this section. Delight and wonder are the main motivating forces for students. And in his mention of universities back East, Carhart calls forth the image of a dispersed cadre of scientists, a dispersion that suggests the need for national publication and societal groups to keep them connected. Part of that process in the nineteenth century was a reorganization of the university and institutions of scientific practice and presentation. As universities, in particular, began to reorganize, the changes in science departments were mirrored in other parts of the university such as the rhetoric classroom, which began to focus on more utilitarian forms of writing.

Scientific writing and writing about science mediated the experience of research for members of all of these institutional configurations. This writing changed to meet the standardized needs of a newly formed, geographically diffuse, impersonal, and imagined professional community. This imagined community was brought into being through the documents, which in turn supported the physical institutions. So, central to both physical and abstract institutions of science is scientific writing and the representation of theories and the individuals making the argument.

The new standardized writing adopted many of the "stylistic abstractions" gleaned from earlier belletristic writing instruction. As these new modes of writing were being developed and the institutional form of scientific research, practice, and teaching was also changing, the main mode of understanding the world was also being developed to accommodate new methods of measuring and seeing the world and to better demonstrate the scientific ethos of individual rhetors. The new institutional contexts and written communication practices of scientists in the nineteenth century also demanded a reformulated understanding of objectivity, which could be demonstrated in writing to distant and imagined audiences.

The Dominant Ethos: Objectivity in the Nineteenth Century

Central to concepts of scientific ethos and epistemology are the dichotomous concepts of objectivity and subjectivity, which by the nineteenth century had become the foundation of both scientific practice and the scientific self. These two terms were (and are) central to how scientists conceive of their judgments. The scientist claims much of his or her ethos from objectivity, and, yet, as a mode of observation, it is a historically bounded practice as well. In the nineteenth century, aesthetics in scientific argumentation was more than, as McAllister would argue, part of the literary epoch. When confronted with esoteric and abstract arguments, ascertaining the rhetor's power of judgment is as important as verifying the content of the argument. Clearly, the presence of an aesthetics of science based in rhetorical history suggests that any persuasion based on these rhetorical tools should be eliminated because of their subjective nature. Indeed, the history of science in the nineteenth century suggests an inexorable march towards more precise modes of objectivity, of knowing the world or at least understanding the objects in the world with the least amount of interference from faulty human perception systems. Objectivity as a mode of performing scientific inquiry has its own historical arc and must also be accounted for when exploring the role of aesthetic judgment in scientific argumentation.

Although objectivity, as generally understood, argues against any serious consideration of the ethos of aesthetics in scientific argumentation, an exploration of objectivity's form and function in the nineteenth century illuminates our understanding of the centrality of the aesthetically compliant rhetor in the scientific argumentation.[36] Perception is a central element of this activity, and rhetorical training served to demonstrate subordination of the unruly, individual taste to a communal understanding of perception that could then be used to judge the rhetor's authority to speak. Taste demonstrated the individual's ability to perceive and theorize. In a very real sense, aesthetic arguments undergirded a philosophy of objectivity and made it a communal process of scientific work.

For instance, the pictorial representations of nature found in atlases of the eighteenth and nineteenth centuries grounded early conversations of objectivity in a conversation of artistic representation. Truth-to-Nature functioned in the eighteenth

[36] See Loraine Daston and Peter Galison's *Objectivity*. They chart the movement of scientific method through "Truth-to-Nature," to "Mechanical Objectivity," to "Structural Objectivity." They argue that each version of objectivity should not be understood as replacing the one before it; rather, each version augments the prior version (Daston and Galison 318). Truth-to-nature was augmented by mechanical objectivity, a practice that supplanted the view and talent of the artist and the editor "to put in its stead a set of procedures that would, as it were, move nature to the page through a strict protocol, if not automatically. Regardless of the method, it shifted focus to the particular rather than the type or ideal" (Daston and Galison 121).

century by standardizing nature by creating standard visual representations of its excessive variety and fecundity. In particular, Daston and Galison point to atlas makers as prime examples of this work. Atlas makers were expected to be familiar with a variety of natural examples and be able to distill the various samples into one perfect representative image (Daston and Galison 95). Daston and Galison argue that this project took beauty seriously:

> [E]pistemology and ethos merged along with the vision of the naturalist and artist. For naturalists who sought truth-to-nature, a faithful image was emphatically not one that depicted exactly what was seen. Rather, it was a reasoned image, achieved by the imposition of reason upon sensation and imagination *and* by the imposition of the naturalist's will upon the eyes and hands of the artist. (98)

In this precursor to modern objectivity, the eyes and hands of the artist were subjugated to the will of the naturalist; the naturalist guides the illustrator in determining the appropriate image to produce in an atlas. The coupling of the new imagination to reason undergirded the process. In later iterations of objective practice, the artist and the scientist are conflated into one figure that deploys reason and imagination to render the appropriate image of nature.

By the mid-nineteenth century, the scientific self, as Daston and Galison argue, was founded on the desire to suppress the individual will. However, a post-Kantian understanding of objective and subjective depends upon an understanding that the subjective self precedes the objective self. Scientific ethos in the nineteenth century relies upon a subordination and suppression of the subjective self through the mechanisms and practices that seek to move natural facts to the page without the "interference" of the subjective self. The objective self arises in post-Kantian scientific practice as a way to practice ethical science. Daston and Galison explain, "The mid-nineteenth century appropriation of the Kantian terminology of objective and subjective in science tended to fuse the epistemological and ethical: the acquisition of knowledge was seen--and felt--to involve a battle of the will against itself" (210). This battle of the will against itself fundamentally defines the desire for an objectivist view of language.

Like aesthetic judgment in science, aperspectival objectivity has a communicative use value when scientists are required to communicate with a diverse audience by referencing core values of science. Objectivity is a slippery term that defines practice, people, and results (Daston, "Perspective" 110). Unlike other forms of objectivity, such as mechanical objectivity, "aperspectival objectivity" is an attempt to eliminate individual idiosyncrasies and make communication across national and disciplinary boundaries useful and successful (Daston, "Perspective" 111-122). Daston explains that aperspectival objectivity was not introduced through the natural philosophy or other sciences but made its way into the scientific community through the moral and aesthetic philosophies of the eighteenth century. While the skill of observation may have been muted in scientific communication of the nineteenth century, the skill of argument was highlighted and codified even further using a rhetoric founded upon the very same moral and aesthetic philosophies of the eighteenth century that were so central to this newest layer of objectivity.

In the nineteenth century, the scientist was presented as engaged in a reserved and morally superior activity, as opposed to the capriciousness of the general public. The communicative necessity and the public face of science created an image of the scientist as an objective observer reporting the factual data of nature. As relationships between scientists in the nineteenth century changed from informal friendships, which Daston argues marked the communication of eighteenth century scientists, to a formalized and more heterogeneous form of communication, the need to erase differences in experience arose as communicability of data became paramount ("Perspective" 117). The phenomena under study had to be made intelligible to a diverse audience who would never be able to experience the particulars of a given observational moment, and, thus, scientists began to rely more and more upon aperspectival objectivity as a means of eradicating the appearance of the unique in their experiences.

Demonstrating the ability to suppress the self (the will), to adhere to community standards rather than personal ones, and to base appropriate judgments about the natural world is central to a scientific ethos of objectivity.[37] The centrality of judgment and scientific knowledge is bound up with these demonstrations, but only in so far as they seek to guarantee the continued good reception of the rhetor. And, as Daston argues in "Fear and Loathing of the Imagination in Science," the scientific self in the nineteenth century was being defined through international projects, which committed scientists to new standards of objectivity ("Loathing" 23). The international scope of these projects added to the broad appeal of objectivity, and through what Daston and Galison describe as an "archeology of objectivity," tasteful judgment, as a virtue in scientific practice, emerged as central to the study of objectivity, because it spoke to the individuals ability

[37] See Daston and Galison's *Objectivity*: "[O]bjectivity is the suppression of some aspect of the self, the countering of subjectivity. Objectivity and subjectivity define each other. If objectivity was summoned into existence to negate subjectivity, then the emergence of objectivity must tally with the emergence of a certain kind of willful self, one perceived as endangering scientific knowledge. The history of objectivity becomes, *ipso facto*, part of the history of the self" (36).

to make appropriate judgments—to having processed the natural world according to community standards and then make statements about that world.

The scientific self, as a product of post-Kantian ideals of objective and subjective, is remediated through a practice of observation and representation that suppresses the will. Indeed, the primary internal struggle of the scientific self is one between the will and the representation of natural world. Rhetorical labor exists at the intersection of these contending forces; it embodies and reflects the contending forces that shaped the scientific self and its ethos in the nineteenth century. The ethos by which scientists base their evaluative claims is itself of construct of larger historical processes, which point to the importance of the scientific rhetor's understanding of community values of judgment and evaluation. Good judgment is an aspect of scientific ethos that was demonstrated through both objective and subjective modes. Being able to determine and explicate the aesthetic qualities of a theory denoted the general ability to judge in the scientist.

Making Way for an Ethos of Taste and Judgment

In the opening example where William James references Maxwell's decision-making process, we see that scientific taste is central to adjudicating between two competing theories. An aesthetic judgment is implied when simplicity is invoked—as is an audience judging whether or not the choice is in good or bad taste. All of this is to say that within that one small apocryphal story is a densely packed series of implications and suppositions as to the individual scientist's faculty of judgment as it pertains to the critical term "taste." Even more complicated is the connection that such a subjective process has with the ostensibly objective mode of scientific ethos, which it was (and is) argued undergirded the entire project of scientific judgment. And, all of this takes place during a period of great technological, institutional, and epistemological change in nineteenth-century American scientific practice. At the center of this change is the scientific rhetor—his colleagues spread across the country and across continental Europe, his work only as good as his words can represent it to this far-flung community. His judgment, displayed through adherence to community values of method and research practice as well as presentation of data in coherent, well-argued theories, is the primary way to demonstrate his scientific ethos within an imagined community of scientific practitioners. Generating the goodwill of his audience through appropriate displays of phronesis (judgment) is central to maintaining a place within the imagined scientific community.

In the examples from Gilman and Carhart, "delight" and "enthusiasm" are the reactions that would engage and drive students and scientists to new heights of intellectual attainments and were to result from new ideas and laboratory experiences, but in reality the language and concepts used to evaluate how those experiences affected an audience's mental state were to come from the study of rhetoric. Aesthetic value judgments in scientific argumentation were more than ornamental; these value judgments were central to engaging the delight and enthusiasm of the audience. Taste, as a critical term that took the mental faculty of judgment as its object of study, was central to that process. It defined the faculty by which the rhetor could judge the natural world and his or her work within the framework of consensual activity of scientific claim making.

Rhetorical education in nineteenth-century American universities is deeply connected to the history of scientific practice in America. As scientific practice was populated with specialized professionals, the rhetorical strategies used by scientists reflected a turn toward a professional practice of science firmly rooted in objective practices of observation and representation—both the lab report and the scientific article became codified in their modern forms during this period. Similarly, rhetorical training, too, took a turn towards the useful in nineteenth-century America. As the century progressed, rhetorical education split into clearly delineated practices—literary studies or belles lettres and practical or useful rhetoric. It would seem, then, that changes in rhetorical education and practice mirrored the changes in scientific practice; both turned towards a clear program of "usefulness" that eschewed aesthetic concerns. However, aesthetic concerns abounded in both scientific practice and rhetorical practice in late nineteenth-century America, and this abundance of the turn towards aesthetics in scientific rhetoric is a field under-theorized and under-researched.

In the nineteenth-century, scientific rhetors made persuasive arguments by explicitly underscoring the relationship between aesthetic appreciation and scientific work. Indeed, beauty and the appreciation of beauty were often the hallmarks of scientific argumentation. Aesthetic judgments reflected an interest in demonstrating scientific ethos as the ability to adjudicate between competing theories of the natural world. The ability to demonstrate this ethos in scientific argumentation took the shape of either the ability to judge between competing understandings of the natural world or by explaining the natural world with an eye towards arrangement and coherence. In the nineteenth century, these two aspects of scientific ethos were themselves theorized and taught in the rhetoric classroom—first as part of a stylistic practice of oratory and later as part of the move towards a written compositional practice. Regardless, the rhetoric classroom was the premier place were judgment and taste were studied and taught as critical components of civic discourse practice—of conceiving of oneself as part of community with standards that must be met through the discourse itself. In the nineteenth century, to adjudicate between two competing theories based on something called scientific taste or to order an argument in a cohesive or simple way was to construct a rhetorical ethos for a scientific audience, which existed in a diverse culture of geographically disparate locals. Above all, this rhetorical construction was central to the creation and maintenance of these imagined and real communities. An ethos of aesthetic judgment was central to representing the practices of science.

CHAPTER 3

SIMPLICITY, BREVITY, AND IMAGINATION: JOSIAH WILLARD GIBBS AND SCIENTIFIC LABOR IN THE NINETEENTH CENTURY

> *The power of rigorous deductive logic in the hands of a mathematician of insight and imagination has always been one of the greatest aids in man's effort to understand that mysterious universe in which he lives. Without the presence of this power, the experimental discoverer might wander in the fields and pick the wild flowers of knowledge, but there would be no beautiful garden of understanding wherein the mind of man can find a serene delight.*
>
> -- F.G. Donnan, "The Influence of J. Willard Gibbs on the Science of Physical Chemistry" delivered in September of 1924
>
> *I had no sense of the value of time, of my own or others, when I wrote it.*
>
> --Josiah Willard Gibbs on his "On the Equilibrium of Heterogeneous Substances"—quoted in William H. Cropper's *Great Physicists: The Life and Times of Leading Physicists from Galileo to Hawking* (110)

Creating the Ordered Garden of Theoretical Science

In his 1924 speech "The Influence of J. Willard Gibbs on the Science of Physical Chemistry" for the centenarian celebration of the Franklin Institute in Philadelphia, F.G. Donnan credits Josiah Willard Gibbs (1839-1903) with what has long been considered a standard compliment for a scientist—that of "imagination" (29). Scientists often credit scientific imagination as a positive attribute, and this speech offers a usual formula for its expression. Donnan lists the accomplishments of Gibbs and the lack of immediate understanding in the American scientific establishment as proof of his far reaching imagination and insight, which were capable of creating a metaphorically verdant (and ordered) garden space so the future experimentalist could fruitfully work.[38] Furthermore, Donnan credits Gibbs' imaginative power with creating the theoretical foundations for lucrative industrial science in the late 1800s and early 1900s. The imaginatively ordered theoretical world is praised for its metaphorical and physical creations. The garden of theory, in Donnan's passage, is crafted from the work of the theoretical scientist, and the metaphorical garden then produces knowledge of the universe and, as we shall see, industrial applications.

Compare this lofty image to Gibbs' terse reflection on his own writing, and the fundamental difference between content and form in scientific writing is illuminated. Donnan values the work of Gibbs—his theories—and Gibbs feels that his writing wasted the time of his readers—he could have written something clearer or simpler. Donnan sees value in the theories, and Gibbs laments their presentation. At the end of the day, Gibbs' theories proved useful and reliable tools for modeling changes in states of matter, and his formulas are still used today.

Donnan's praise of Gibbs' scientific labor obscures several important elements of the communicative aspect of scientific work. For one thing, hardly anyone understood Gibbs' work at the time of its publication. Even the committee of professors who agreed to publish his works in the first place was at as much of a loss as other scientists of the

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[38] In particular, see Leo Marx's *The Machine in the Garden*, where he argues that the image of the garden in American literature and culture is an expression of utopian desires (43). Donnan's garden of theoretical delights is as utopian a vision for scientific practice as one could imagine.

era as to the content of Gibbs' work.[39] Far from being a genius who immediately gained recognition or a firebrand globetrotting intellectual whose personality and wit convinced scientists of the correctness of his work, Gibbs was an obscure and reserved theoretician from Yale University who never traveled widely. His complex, theoretical work was disseminated in writing, and his terse prose and mathematical glyphs were the only contact interested scientists had with his mind. His scientific labor, the work that created Donnan's imagined garden of theoretical delights for the experimentalist, was the written argument. Donnan and others would later find in Gibbs' imagination the starting point for valuable experimental and industrial practice. Gibbs' argumentative work is assimilated into a totalizing evaluation of the labor of the scientist; in Donnan's estimation, theory seems to exist outside of language's constitutive realm. But Gibbs' comment demonstrates he was more aware of language's centrality to his work—demonstrating his imaginative work through the act of the writing was a concern for Gibbs. His imagination must be legible in the written presentation as well as the mathematics. The connection between these two modes of generating ethos are important for understanding the interventions of formal rhetorical training in his articles and the scientific community's reception of his work.

The response to Gibbs' theories suggests two competing narratives about his work. On the one hand, his theoretical work is a powerful tool for organizing scientific

[39] In his 1925 article, "How the Works of Professor Gibbs Were Published," A.E. Verrill recounts the difficulties the publishing committee had with understanding Gibbs' work: "Two able mathematics professors were on the committee—Loomis and Newton. Both protested that they did not understand Gibbs' papers at all. One insisted that no man who ever lived who could understand them except Maxwell, and he was dead. Yet we all believed that what Gibbs wrote must be of intrinsic value in his branch of science" (42).

labor through mathematical intervention, and on the other hand the actual paper is difficult to read. However, this seeming contradiction should not be considered an either or response to Gibbs' work; indeed, some of his contemporaries found it both clear argument and difficult reading. In "The Scientific Style of Josiah Willard Gibbs, " Martin J. Klein cites Wilhelm Ostwald, the German translator of Gibbs' papers, who, as Klein tells it, explained to potential readers "that Gibbs had chosen his mode of exposition, 'abstract and hard to understand,' in order to achieve 'the greatest possible generality in his investigation and the greatest possible precision in his expression'" (142). The difficulty Gibbs' audience experienced while trying to understand his work was not caused solely by the inclusion of mathematical formula in his presentation. Indeed, James Wynn has recently argued in his book *Evolution by the Numbers* "novel mathematical arguments used to make claims do not necessarily compel acceptance" (7). Furthermore, the predominant philosophical attitude towards mathematical interventions in scientific research suggested that its use in the nineteenth century should be understood within the context of the debates of how best to understand natural phenomena (Wynn 23). It had the potential for being a powerful tool for understanding natural phenomena, but it was not a readily and unquestionably accepted tool. In this light, we can understand the difficulty that Gibbs had with explaining the functions of his mathematical work and the desire to present it as a useful and accessible tool (on some levels) that should be adopted.

Gibbs' scientific ethos is generated, in part, through his overt interest in presenting his ideas. The competing responses to his papers are reflections of the conflicting impulses in his own writing, which seem to stem from his desire to advocate for his mathematical work, in part, based on its ability to help clarify natural phenomena and the ease with which it would allow scientists make calculations. However, his prose style is dense and the mathematics technically sophisticated, so the majority of the paper is difficult to grasp for the typical audience that would be reading his work. It is here that he falls back on an understanding of presentation that echoes one found in the Scottish New Rhetoric textbooks available at the time. He advocates for his work by continually highlighting its (supposed) simplicity. In his papers, Gibbs echoes the standard advice given to students in rhetoric classrooms in texts such as Richard Whately's *Elements of Rhetoric*—writers must always consider the presentation of their work. Style of presentation is as important for generating audience understanding, as are the merits of the argument. For Gibbs, discussions of style found in his work are as important as the actual execution of stylistic elements in his papers. In these early papers, Gibbs must demonstrate technical as well as stylistic judgment.

This chapter shows that Gibbs used his formal education in rhetoric to advocate for his theories and craft an experience of those theories for the audience that adheres to communal aesthetic values. In doing so, he creates a scientific ethos reliant upon aesthetic judgment of arguments as well as mathematical ingenuity. Relying upon disciplinary knowledge *and* formal rhetorical training to advocate for his theories, Gibbs demonstrates how rhetorical interventions are necessary for crafting coherent arguments; those rhetorical interventions are, in turn, not seen as rhetorical but part of the labor of science. Rethinking these interventions as rhetorical in nature can allow an examination of how scientific argument is grounded in rhetorical training. As James Berlin explains in *Writing Instruction in Nineteenth-Century American Colleges*, nineteenth-century New

Rhetoric taught that "[l]anguage and things are considered separate, but the discussion of style—perspicuity, energy, vivacity, and the like—becomes central because of the importance of language to reproducing the content of experience in the minds of the audience" (8). Since a major facet of the nineteenth-century scientific article was theorizing on the basis of and connection between natural facts, theorizing itself, the "tightness of fit between nature and its symbolic representation," became an object of discussion for scientists (Bazerman, *Shaping* 33). Simplicity and brevity were two methods that ensured a fit between nature and symbol, and two methods which Gibbs used to construct an argument for coherence in his theories.[40]

Confronted with the task of representing inaccessible phenomena to a scientific cohort familiar with demonstration machines and biological specimens, scientists relied on language practices that had been more readily available to earlier natural philosophers. Woven into discussions about mathematical formulas, matter states, and graphical methods, readers found appeals to their aesthetic sensibilities and explanations as to the form of arguments that would disappear into the terse writing of twentieth-century theoreticians. In Gibbs' work, the aesthetic object is not nature but the theoretical models he used to discuss nature. In the absence of the physical world, the scientist's ability to produce convincing models is celebrated rather than his or her ability to find and

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[40] In this chapter, I use the definition of coherence that Andrew Pickering sets forth in "Living in the Material World: On Realism and Scientific Practice." He suggests that coherence in scientific practice results from the use of models and that material resources are "plastic resources for practice" (279). The scientist creates coherence through the use of these elements arranged in a contingent manner to provide data with which to theorize. Furthermore, in "The Beauty of Symmetrical Design: The Alleged Epistemic Role of Aesthetic Value in Theoretical Science," Gregory Morgan has recently outlined how William Whewell, noted philosopher of science in the 19th Century, valued coherence as an aesthetic value of a theory that demonstrated beauty within a theory (6).

catalogue specimens of natural beauty. A scientist's labor is then two-fold—he or she must first craft the mathematical and theoretical scientific work, and then he or she must convince others of its efficacy. In particular, coherence, as arrived at through arrangement in an argument is a value that many scientists, past and present, accept as having an effect on evaluations of Gibbs' theoretical work. For many scientists, Gibbs' authority rested on his skill in arrangement, and the adoption of his theories, in part, relied upon his ability to produce a coherent document. The coherence of his papers' arguments is a direct demonstration of his capability to judge both his field and his heterogeneous audience appropriately.

This rhetorical work was deemed valuable scientific labor in the nineteenth century. Mathematics, although basic, was not highly valued outside of circumscribed fields such as mechanical engineering. Rhetoric, on the other hand, was a much more immediately valued subject and universally taught. Scientists educated in early nineteenth-century universities in the United States were exposed to extended training in rhetorical practice through a strong liberal arts education. Scientific rhetors relied on this training to communicate their work in the changing terrain of the sciences in the nineteenth century; a communal sense of the aesthetic worth of scientific practice could only be maintained within the confines of argumentation. After economic changes led to a revision of the university curriculum, the extra-communal value systems remained largely intact. Aesthetic worth was no longer invested in scientific objects but shifted to scientific practice, as the ability to theorize became a central labor for scientists in the latter half of the nineteenth century.

Simplicity and brevity in scientific argumentation are, then, marks of aesthetic qualities of the argument that signify the presence of coherence, the much desired effect of scientific theorizing. Using the early work of Josiah Willard Gibbs in physical chemistry and Richard Whately's *Elements of Rhetoric*, this chapter explores the relationship between scientific argumentation and formal rhetorical training; this relationship supports the ongoing aesthetic evaluation and conceptualization of theorizing as a creative, imaginative act. In particular, I am interested in exploring the role of "indirect values" in Gibbs' efforts to advocate for the adoption of a new theoretical standpoint.[41] This chapter gives a brief history of J. Willard Gibbs with an emphasis on his university training; gives a brief overview of the academic culture of science in Gibbs' life; delineates Whately's rhetoric and its specific concerns with elegance, perspicuity, and the metaphor as markers of his inductive rhetoric and as formal elements in a mechanistic conceptualization of the mind; examines two articles and one abstract, as illustrations of Gibb's use of his rhetorical training; and finally, explores how Gibbs' rhetorical labor of crafting coherent arguments are evaluated when his theoretical science is celebrated.[42]

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[41] I refer to Kevin Elliot's work to distinguish between "direct values" and "indirect values" in theory choice. In "Direct and Indirect Roles for Values in Science," he distinguishes between normative values associated with epistemology and other "murky" values that, while not central to doing accepted experimental or theoretical practice, affect the choice of theories (317).

[42] The exact terms that Gibbs and Whately use to reference elements of the text do not match exactly. As will be demonstrated, Gibbs references "simplicity" and "brevity" in a fashion that clearly suggests he thinks of them as the same elements of argument as Whately's "elegance" and "perspicuity".

Gibbs' use of simplicity, brevity, and metaphor in his scientific writing exemplifies how "extra-empirical" values shape scientific activity. These critical terms (simplicity and brevity) illuminate the very real connections between rhetoric and scientific practice that are often elided when attempting to address what seem like long-held epistemological concerns of mathematics or what some may believe are philosophically grounded aesthetic concerns of theoretical science. Highlighting these connections allows us to see the ways in which aesthetic value judgments originating in rhetorical study have persuasive power in highly technical arguments. For Gibbs, the rhetorical tools of simplicity and brevity are both elements of the formal qualities of beauty in mathematical reasoning, but in these instances they also denote non-mathematical values of his argument.

Forced to address diverse scientific audiences, Gibbs relied on the concepts of simplicity, brevity, and the metaphor to carry much of the weight of his argument as he self-reflexively engaged with his own concerns about writing and audience perception of his ideas, but these terms also had a dual meaning in mathematics. Historically, the mathematical meaning has been what scholars believed Gibbs referred to when using them. Often in theoretical science, scientists refer to concepts like simplicity and brevity in an attempt to support their theoretical stance. However, I argue that these also offer themselves up to rhetorical analysis if we consider them as vestiges of historically bound argumentative practice. Simplicity and brevity do have a history as mathematical terms, but they also have a relationship with rhetorical terms in the Scottish New Rhetoric of the eighteenth and nineteenth centuries.

The flexibility of specific aesthetic terms allows scientific rhetors to demonstrate an appropriate ethos by aligning themselves with aesthetic values that appear to be universal. Simplicity and brevity have been used as evaluative criteria in mathematics since Euclidian geometry.[43] This chapter explores how those extra-empirical criteria obtain during the rhetorical work of scientific argumentation. These extra-empirical criteria do not contradict or undermine a theoretical science that attempts to model the world as experienced. Rather, this extra-empirical, rhetorical labor is an important aspect of scientific argumentation in the absence of a field-knowledgeable audience or a firmly formatted argumentative template accessible to all readers of the article. Gibbs uses these rhetorical tools when advocating for the coherence of his argument. They are also the very attributes of his argument that are later evaluated as part of the beautiful imaginative work of theoretical physical chemistry. As such, they are most assuredly the product of Gibbs' undergraduate training in rhetoric; his exposure to Richard Whately's *Elements of Rhetoric*, a central text of the Scottish New Rhetoric, would have been a formative experience. In particular, the Scottish New Rhetoric's focus on arrangement and style as a direct reflection of the rhetor's mind are clearly at play in Gibbs' concern with representational simplicity and intelligibility in his written work. Gibbs actively engages these extra-empirical criteria, a central part of scientific culture in the nineteenth century, throughout his work.

[43] See James McAllister's "The Simplicity of Theories: Its Degree and Form." Simplicity plays both a logico-empirical role and quasi-aesthetic role in scientific theory-choice (1). He states, "scientists apply in theory-choice not only logico-empirical criteria which are diagnostic of theories' future success, but also extra-empirical criteria which do not lend themselves to this diagnostic role [and] . . . are frequently characterized as 'aesthetic'" (2).

J. Willard Gibbs: From Mechanical Engineer to Physical Chemist

Josiah Willard Gibbs was a physical chemist trained as an engineer responsible for producing equations that plot states of matter as it undergoes transformation from a gas to a liquid to a solid. He was born in New Haven, Connecticut on February 11, 1839 and, with the exception of post-graduate work completed in Europe, spent his entire life and career at Yale in New Haven. Gibbs came from a long line of Harvard and Yale graduates. His father Josiah Gibbs Sr. was a well-respected professor in the Yale Divinity School and had gained some fame for his involvement in the *Amistad* case, having helped find a translator for the defendants (Rukeyser 36-38). Following in the footsteps of his father, young Gibbs attended Yale undergraduate and graduate school. He completed his undergraduate degree in 1858 at the age of 15. The Sheffield Scientific School at Yale awarded him his PhD in Engineering in 1863. He then spent three years as a tutor in mathematics and Latin, and in 1866 sailed for Europe to spend three years in post-graduate study in Paris, Berlin, and Heidelberg. While in Europe, he was introduced to theoretical thermodynamics, a field not widely studied in the United States.

Gibbs' undergraduate training at Yale included specific instruction in Richard Whately's *Elements of Rhetoric* (Yale University). The third term of the sophomore year at Yale between the years 1850 and 1871 required that all students read *Elements of Rhetoric* except for section IV "On Elocution." Yale, like many American universities at the time, had not yet adopted the German model of higher education with its specialized disciplinary focus. Students were taught a liberal arts tradition aimed at creating a citizenry with a breadth of knowledge and ability to act civically. Rhetoric was a foundational part of this training. During the same period, Gibbs excelled at Euclidian geometry, which was despised by many of his peers.[44]

After completing his studies at Yale, he traveled to Europe for more extensive theoretical training, which some believe to have influenced his future mathematical work. Unfortunately, there are no existing letters or other memorabilia from this time period; with the exception of this time in Europe, Gibbs lived his entire life in New Haven; he took his sisters with him to Europe, so there were no letters sent home (Knudsen 271). Only his notebook survives, full of mathematical formulas and names of courses he took but not much else. Knudson argues the evidence points to only an indirect influence seen in certain tendencies of his mathematics (278). Regardless of whether there was a direct or indirect influence on Gibbs' mathematical work, his time in Europe seems to have altered the trajectory of his career from mechanical engineering to more abstract and theoretical work. However, this change was not a total departure from his previous work; rather, it was an outgrowth of his mathematical aptitude exhibited in his master's thesis.[45] His undergraduate, graduate, and post-graduate training in mathematics marked him as disciplinarily different from his scientific peers in the United States.

In the mid-1800s, newly minted PhDs in the sciences, trained in European universities and versed in the language of cutting-edge theoretical thinking, were coming

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[44] Muriel Rukeyser tells the story of how at the end of the sophomore year, Yale undergraduates participated in the "Burial of Euclid." This colorful ceremony included hooded and robed students, images of Euclid in Hell, and the burning or burial of Euclid's *Geometry* (96-97).

[45] Martin Klein argues in "The Scientific Style of Josiah Willard Gibbs" that his basic mathematical reasoning did not change so much as his object of analysis shifted (144).

back to the United States and communicating their projects to older, more established colleagues unfamiliar with the newer fields and theories in Europe, and they had to rely on their rhetorical training to make their arguments persuasive. Since a strong mathematical background was necessary to theoretical science, nineteenth-century American mathematicians were at a disadvantage when communicating their theoretical work, and many older American scientists were more at home in the laboratory or the field than in the world of abstract reasoning. John Servos explains in "Mathematics and the Physical Sciences in America, 1880-1930" that it was not until the second half of the nineteenth century and the influx of students returning from German and other European universities that mathematics and physics received more attention (612-613). As these fields grew in the United States, so too did the institutions supporting them. Furthermore, the scientists who "attained eminence in the physical sciences prior to 1930 generally did so for making precise measurements of physical constants or for innovations in the instruments of measurement rather than for theoretical contributions" (Servos 142). Although this brief history suggests that Gibbs' later training diverged from that of his scientific peers, his early liberal arts training was common ground for professional conversations with them.

Richard Whately's *Elements of Rhetoric* and Elegant Composition

Richard Whately's (1787-1863) *Elements of Rhetoric* was first published in 1828 and is counted as one of the more widely distributed and influential rhetorics in nineteenth-century America. It was the only one of the three Scottish New Rhetoric books published in the 1800s, and by the time the book had reached its seventh and final revision in 1846, *Elements* had been revised and expanded beyond its original scope and length (Golden and Corbett 273-274). Whately also demonstrates that he specifically addressed the rhetorical scholarship of Hugh Blair and George Campbell, making this text the most recent in the century and most complete discussion of the Scottish New Rhetoric used in American universities. While not every university student was exposed to this particular book, many students used rhetoric textbooks that took it as their inspiration. For example, Whately frequently discusses Blair's work in his text, sometimes agreeing and amplifying a point of his and sometimes using Blair's work as a foil for his own—arguing against a perceived fault in his work to sharpen his own argument. Jean Ferguson Carr, Stephen Carr, and Lucille Schultz report in *Archives of Instruction* that Whately's *Elements of Rhetoric* along with other rhetorics had ten or more editions printed in the years 1831-1865 (49). They also explain that rhetorics where for "wide adoption" on a national level rather than locally used and *Elements* can be understood as a nationally circulated text with wide distribution. Indeed, James Berlin argues that Whately's rhetoric survives today as Current-Traditional composition (9). The longevity of Whately's project speaks to presence of his concepts of style in nineteenth-century writing. Its presence in so many rhetoric and composition courses throughout nineteenth-century America ensured that Whately's faculty psychology approach permeated composition instruction throughout the century.[46]

[46] In "Rhetoric, the 'Citizen-Orator,' and the Revitalization of Civic Discourse in American Life," William Denman argues for an understanding of the long-reaching effects of formal rhetorical training in the universities, Denman reminds us that the rise of the culture of professionalism and new disciplines helped carry out the ideals of the New Rhetoric and transform them at the same time (4).

Whately' rhetoric stresses arrangement of ideas as opposed to invention, which reflects his life in the church, the law, and as a scholar. Richard Whately was known primarily for his work as a political economist and as the archbishop of St. Patrick's Cathedral in Dublin (Golden and Corbett 273-274).[47] Karyn Charles Rybacki, quoting Craig Parton, notes Whately's defense of Christianity focused on the idea that "'faith rested on evidence, which must be weighed by the use of reason'" (ix). Whately's dedication to his religion took the form of arguing for a reasoned approach to faith whereby the faithful arrive at assent to dogma through the exercise of their mental powers using pre-existing evidence to support their thinking. His approach to argument stresses arrangement over invention, and stylistic elements of clarity and perspicuity are necessary to properly arrange the argument, and aesthetic concerns, while not trumping facts, do have weight in arguments in Whately's formulation of rhetoric.

Instead of inventing topics for discourse, Whately encouraged students to manage the factual material they had found so as to persuade the audience.[48] As James Berlin outlines in his book *Writing Instruction in Nineteenth-Century America*, Whately

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[47] Whately's faith and experience in the church had a definite influence on his writing, and Douglas Ehninger reminds readers in the "Editor's Introduction" that "*Elements* is predominantly an ecclesiastical rhetoric" (ix).

[48] *Elements of Rhetoric* defines a clear path from evidence to presentation. In the book, Whately extends his project started with *Elements of Logic* and seeks to create a "'regularity of system' in the procedures for the discovery and arrangement of arguments" (Johnson, *Nineteenth-Century* 51). Whately argues, Bizzell and Herzberg explain, that Aristotle is the "best of the lot" and sees his rhetoric as a return to a systematic study of how persuasion creates conviction (1000). Although Whately created his rhetoric with religious orators in mind, the ways in which he construed the arrangement of evidence at both the macro-level of the sets of evidence and examples and at the micro-level of the sentence highlights his interest in the management of the argument so as to create the maximum effect on the audience.

(following the lead of Campbell and Blair) articulates a mechanistic conceptualization of the role of rhetoric. This "managerial" style of composing mirrors the allegiance to inductive scientific thinking that defined the Scottish Common Sense School of philosophy. The composing process, in Whately's formulation, articulates relationships between information rather than creating new information before the audience's eyes. In this way, the Scottish New Rhetoric trains young rhetors in the logic of scientific induction. Whately's perspicuity, energy, and elegance are variations of simplicity and brevity as modes of presentation and descriptors of relationships between facts. These variations in turn illuminate the ways in which rhetoric is managerial or mechanistic. By adhering to Whately's dictates, the writer can arrange the presentation of arguments in such a way as to elicit a desired response from the audience. This response is ultimately out of the control of the writer, but the relationship with the reader is one in which the writer demonstrates his or her mental faculties to the audience. Simplicity and brevity demonstrate that the interiority of the writer is elegant, and it this demonstrated mental prowess that helps command agreement.

Nan Johnson explains in *Nineteenth-Century Rhetoric in North America* that the Scottish New Rhetoric is a product of Campbell and Blair's synthesis of an exploration and codification of the study of "the processes of the 'mental faculties'" and the aesthetic concerns that accompany the "critical study of rhetorical theory and the development of taste" (Johnson 46).[49] Johnson further explains that one of the Scottish New Rhetoric's

[49] See Lois Agnew's "The Civic Function of Taste." The New Rhetoric focused on style, bound by the restrictions of the culture in which rhetors found themselves (Agnew 32). Although Lois Agnew explicitly addresses the work of Blair, we can understand this to be part of the larger product of the New Rhetoric.

projects was the training of taste through language. In Whately's extension of that project, he explicitly sought to write a rhetoric textbook to aid "unpractised writers" (xxxvii). Johnson urges rhetoricians to think of nineteenth-century rhetoric "as synthetic of 18^{th} C rhetorical philosophers – Blair, Campbell, and Whately and 19^{th} C rhetorical theorists who combined belletristic treatments of the principles of taste, style, and the literary genres with epistemological discussions of the laws of the mind" (*Nineteenth-Century* 14). Whately presents the Scottish New Rhetoric as a set of practices aimed at mastering the production of writing rather than a set of criteria with which to enact criticism of a text. Gibbs' undergraduate training most certainly brought him into contact with Whately's instruction based on the New Rhetoric, which fostered a systematic way of writing intent on training writers to craft texts that appealed to reason through taste.

Stylistic elements drive the choice of appropriate arrangement in Whately's rhetoric, but these elements are not to impinge on the content of the argument; the elements are central to presentation and are not substantive. Whately introduces his *Elements of Rhetoric* explaining to his readers, "The process of investigation must be supposed completed, and certain conclusions arrived at by the process, before he begins to impart his ideas to others in a treatise or lecture; the object of which must of course be to prove the justness of these conclusions" (5). For Whately, as for his compatriots, rhetoric's primary function is arrangement. In "Consistency in Richard Whately: The Scope of His Rhetoric," Lois J. Einhorn explains that while Whatley often seems to give contradictory or unclear instructions as to the scope and point of his rhetoric, he clearly demonstrates that he is concerned with managerial rhetoric. This managerial rhetoric takes already perceived truths and explains the best methods for managing their arrangement in argument. In particular, Whately discusses the functional aspects of style that are central to "conveying thoughts" (Einhorn 93). The three parts of perspicuity, energy, and, above all, elegance are addressed at length in Whately's textbook. Each element of style is explained through its effect on argumentative composition.

Elegant Arrangement in Whately

In Whately's *Elements*, elegance is the most complicated of the three items, and Whately spends considerable time in "Of Elegance" discussing the importance of the appropriate type of presentation. Although Whately explains to the reader "On the last quality of Style to be noticed,---Elegance or Beauty,---it is the less necessary to enlarge" (328), the chapter is the only place that specifically details how to balance the three elements of style—perspicuity, energy, and elegance—when presenting an argument. Although elegance in Whately's textbook refers to poetic language, he believes this chapter is the appropriate place to discuss the rhetor's duty to deploy stylistic elements that best support his argument. In doing so, the rhetor must be conscious of the effect style will have on the audience. Considering elegance forces the rhetor to make stylistic choices that reflect his goals, and by doing so the rhetor must find a managerial balance among the elements of his argument and the manner in which they are presented. To strike this balance, the rhetor must consider all of the elements of style at once. This choice includes deciding especially on the clarity and manner in which the text inspires the audience. So, Whately focuses on the sentence-level usage of language as well as metaphoric and technical language. The overall effect suggests that there are many elements of style that must be considered when finalizing a text for a specific audience.

"Part 3" of *Elements* is divided into three chapters: "Of Perspicuity," "Of Energy," and "Of Elegance." Each chapter builds upon the one before it, but perspicuity and energy are discussed separately in "Part 3." However, they play a central role in Chapter 3 "Of Elegance" in a way that elegance does not in the preceding two chapters. Indeed, the final line of Whately's "Part 3" (and coincidentally the final line of the text as taught in Gibbs' undergraduate years when the course in rhetoric explicitly ignored the final section of the book "Part 4: On Elocution") warns students:

> He [the rhetor] should carefully study *Perspicuity* as he goes along; he may also, though more cautiously, aim, in like manner, at Energy; but if he is endeavouring (sic) after Elegance, he will hardly fail to betray that endeavour (sic); and in proportion as he does this, he will be so far from giving pleasure, to good judges, that he will offend more than by the rudest simplicity. (338)

Whately spends most of the chapter on elegance cautioning students from the overuse of stylistic flourishes that would complicate their presentation and unduly confuse the audience, and he culminates these warnings with this final admonition—advising students to consider all of the elements of style. It is clear that Whately's understanding of elegance highlights the belletristic nature of this element of style, but I argue that just as clearly Whately instructs readers to use their judgment in knowing when and how to use elegance in their writing. Elegance, then, points to the judgment in a way that encompasses all other elements of style in Whately's rhetoric, placing them in service to effectively arranged arguments. To understand how elegance can be a site for this type of aesthetic judgment, we must understand the two preceding elements of style—perspicuity and energy.

The driving goal of appropriate arrangement is clarity and audience understanding. In Chapter 1 "Of Perspicuity," Whately explains that this first stylistic element is a "relative quality," which must take the audience's ability to understand into consideration (258). Indeed, it seems that intelligibility for the audience is a primary concern for perspicuity, and Whately warns against being too brief in explanations (259). Furthermore, Whately explains, "nor are the ornaments of style . . . necessarily inconsistent with perspicuity; indeed Metaphor, . . . is . . . the clearest mode of expression that can be adopted" (262). Audience understanding is central when the rhetor makes judgments as to what constitutes perspicuous language in a particular argument. For Whately, perspicuity is one of the highest aims for the elegant rhetor wishing to write clearly. Perspicuity engages the mind of the reader and is conducive to his or her understanding and willingness to listen to the orator. Audience is so important in Whately's conceptualization that he makes sentence-level prescriptions, which suggest that he does see a concrete connection between all levels of rhetor choice and intelligibility:

> A well-constructed sentence of very considerable length may be more readily understood than a shorter one which is more awkwardly framed. If a sentence be so constructed that the meaning of each part can be taken in as we proceed, (though it be evident that the sense is not brought to a close,) its length will be little or no impediment to perspicuity; but if the former part of the sentence convey no distinct meaning till we arrive nearly at the end, (however plain it may then appear,) it will be, on the whole, deficient in perspicuity; for it will need to be read over, or *thought over*, a second time, in order to be fully comprehended; which is what few readers or hearers are willing to be burthened with. (263)

At the sentence level, Whately advocates for an awareness of perspicuity's effect on the audience; it can order and sustain an audience's experience of the argument. A well-executed, perspicuous argument will not have to be read or *thought* twice, and sentences should be arranged to ensure perspicuity and vivacity in the writing. In this brief example of sentence-level perspicuity, the audience's experience of understanding the argument is of paramount importance.

Well-executed presentation then is about being appropriately perspicuous; the rhetor is warned to explain what needs to be explained and always consider the audience when judging what should be included and how it should be presented. As an element of style, perspicuity also tasks the rhetor to contend with successful presentation as something that does not solely rely on knowledge of a field or argument. This will become even more important when it is imported into the discussion about elegance at the end of the section, since determining audience knowledge of the field is so important for gauging the appropriate use of stylistic elements. Critiquing Blair's argument that an unclear style comes from a misunderstanding of a subject, Whately argues the converse—that when a rhetor knows his or her subject well the "principles which by long habit have come to assume in our minds the appearance of self-evident truths" (264-65). Once clarity has been achieved, the rhetor can move on to consider the second element of style—energy.

The second element of style is energy, and it introduces the student rhetor to the importance of word choice and arrangement to address the needs of a particular audience. In his chapter on energy, Whately explains that it is analogous to Campbell's "vivacity," and it refers to everything a rhetor does to "stimulate attention,--to excite the Imagination, and to arouse the Feelings;" furthermore, energy, like perspicuity depends on the choice, number, and arrangement of words (275). When energy is introduced into the discussion of elegance, it is given primacy over the more poetic language, but only in so far as it can excite the imagination of the audience about non-poetic discussions. Particularly important for scientific language is Whately's focus on the effects of technical language and metaphor on energy.

Of particular importance for later discussions of Gibbs's writing is Whately's discussion of metaphoric and technical language. Both are discussed with specific connections to energy; Whately considers metaphoric language conducive to energy, and he warns that overly technical language can take away from it. In particular, the metaphor adds energy to the argument because it can "attribute life and action to things inanimate" (Whately 283-84). As useful as metaphors are to creating energy in a text, they are not to be confused with examples, which are useful for issues explaining abstract concepts. "On the other hand it is important to observe, with respect to any imaginary case, whether introduced as argument, or merely for the sake of explanation, that, as it is requisite that the hypothesis should be *conceivable*, and that the result supposed should be followed *naturally* from it, so, *nothing more* is to be required" (Whately 105). Whately explains that examples should not be used to prove anything; examples are for advocating and making one's argument understood by the audience. But metaphoric language is about exciting the imagination and creating interest in the audience. When it comes to technical language, on the other hand, he admonishes his students "against the unnecessary introduction of TECHNICAL language of any kind, when the meaning can be adequately, or even tolerably, expressed in common, i.e. unscientific words" (Whately 294-95). These two discussions of language use would seem to argue against any use of language other than the most basic, commonly understood images and terms, but

Whately's understanding of the uses of metaphor and technical language always suggest that the intended audience should be considered when making these choices.

Having explained in detail the previous two elements of style to student rhetors, Whately proceeds to discuss elegance. In this culminating section of Part 3, Whately incorporates his prior discussions of perspicuity and energy into a discussion of elegance. When a rhetor is considering elegance, he or she is really making an informed choice between clarity and ornamentation; the most successful forms of elegant prose strikes a balance between the two. This balance is even more important because the rhetor must strike it in the context of "having something to say" (Whately 329). It is this difference between research and presentation that the rhetor must consider.

For instance, Whately explains that metaphors (a principle feature of energy) may be "striking" and "apt" for the argument and "conducive to Energy of expression" but a metaphor may also "have no intrinsic beauty" (328). Indeed, he warns readers that they must avoid the appearance of being too polished for it will reduce the "force of what is said" (Whately 329). Ultimately, the rhetor must choose based on the content being presented and the audience's taste and level of understanding. Scientific writers are especially burdened in this regard in Whately's text precisely because they must contend with many of the presentational choices that Whately sees as part of style. The scientist must be clear, excite the imagination of the audience, and consider language choice wisely.

In particular, Whately instructs student writers to remember that the more complicated the argument, the more important it is for the writer to simplify the presentation. He closes the chapter by revisiting that particular point, arguing that the "rudest simplicity" is far preferable to elegant prose when presenting complicated material to an audience unfamiliar with the material (Whately 338). Although the final chapter in the style section focuses on elegance and ornamentation, Whately returns to "simplicity" as a way to highlight the importance of intelligibility for his student writers. Clearly, he instructs students to think of their audience's needs when composing texts.

Whately gives more focused instructions when it comes to scientific writing and professional ethos. The philosopher and orator combine in the example of the scientific writer and demonstrate the centrality of stylistic considerations to all argumentation. In this example, perspicuity becomes central to scientific argumentation because it bridges the gap between the philosopher and the presenter. For Whately, a lucid prose style is the central goal of the scientific writer:

> Perspicuity is required in *all* compositions; and may even be considered as the ultimate end of a Scientific writer, considered as such. He may indeed practically increase his utility by writing so as to excite curiosity, and recommend his subject to general attention; but in doing so, he is, in some degree, superadding the office of Orator to his own; as a Philosopher, he may assume the existence in his reader of a desire for knowledge, and has only to convey that knowledge in language that may be clearly understood. (331)

Whately distinguishes between the two activities of research and presentation – the Philosopher and Orator – in order to highlight the importance of choosing the most appropriate style. Choosing a style for one's presentation is a matter of professional identity. Whately makes it clear that the scientist is no orator. The content alone should be enough to excite the reader, but Whately's instructions imply that the scientific writer still has choices to make when it comes to the effect his writing will have on the audience. These choices, according to Whately's instructions, do affect the outcome of the presentation—the reception of the scientific content. The arrangement of words and the arrangement of data are working to create the most efficient argument possible. The choice also reflects the presentation values and commitments of the scientist.

One useful way to consider the separation of research and rhetorical labor outlined above is to consider how Whately differentiates between inferring and proving in order to separate the activities of research and presentation. Disciplinary knowledge and argument are two separate entities in the *Elements of Rhetoric*, where Whately argues for the conceptualization of this split between discipline knowledge and argumentation. Lloyd Bitzer argues in "Whately's Distinction Between Inferring and Proving" that for Whately investigation is motivated by a rhetor's desire to seek truth and infer new ideas by working from premises. First the rhetor must complete his or her research before he or she can advocate for the findings. Proving is an act of advocacy that does not necessarily have "truth-seeking" as its motivating force (Bitzer 333). This is not to suggest that advocates are dishonest; it merely is an attempt to separate out the two activities inherent in rhetorical work. As Bitzer outlines, Whately's formulation of the act of inferring and the act of advocacy exists on a scale of activity with "the philosopher" who infers on one side and the advocate who presents arguments on the other (314). Bitzer observes there is an overlapping space where the two behaviors mingle within this range of activities. This middle space can be managed by the rhetor in the process of composing an argument from the material uncovered through research.

Whately's overt concern with style and arrangement for achieving a clear and useful prose is central to his theories about composition of arguments, especially in relationship to scientific writing and the importance of adjudicating between technical language, abstraction, and clarity. The introduction of elegance in his rhetoric and the concept's existence in scientific thinking is not coincidental; rather, it underscores how both fields approach a valuation of mental labor. Whately does not focus on style for style's sake; rather, style is central to the creation of an experience for the reader that best supports the rhetor's goal of inspiring understanding and consent from the audience member in an honest and logical manner. We can understand that drive as similar to the drive in scientific argumentation to consider form and content of an argument. In "When Simplicity, Practicality, and Significance Meet: Elegance in Scientific Computation," Baker Kearfott outlines the elements of elegant solutions for a mathematician. His argument suggests that the scientist's understanding of presentation and argument is quite similar to the Scottish New Rhetoric's presentation of the term: "[E]legance in mathematical sciences means 'simultaneously easy to state and understand, yet powerful and revolutionary, with wide-ranging consequences.' Elegance in mathematics leads to insight and easy understanding of relationships in the physical world and concepts within the philosophical world" (Kearfott 41). While elegance as a term means something slightly different for Kearfott and Whately, the choice is the same for the scientist when crafting arguments for an audience. Like Whately's use of elegance as the impetus for stylistic choices, Kearfott's argument suggests that ease of understanding and inspirational insights are paramount to a successful argument. Central to crafting stylistically successful arguments is the act of balancing the needs to the audience with the needs of the subject matter. In the case of Gibbs' papers, the national and international audience largely lacked the technical background necessary to understand the core of his argument. Gibbs had to rely on other ways of demonstrating his scientific ethos for his audience.

Gibbs' Publishing History, His Audience, and the State of Physical Chemistry in Nineteenth-Century America

In the 1870s, Gibbs published two important papers in The Connecticut Academy of the Arts and Science's *Transactions of the Connecticut Academy*. The Connecticut Academy was a regional institution that drew its membership from local colleges and did not often have the chance to engage in international scholarship.[50] Gibbs' first paper "Graphical Methods in the Thermodynamics of Fluids" published in 1873 articulated a new geometrical method for charting thermodynamic energy in different bodies of matter, but did not find a suitable audience for its work in the local academy. The limited distribution of the *Transactions* demonstrates a typical dilemma for the nineteenth-century American scientific rhetor. The intended audience is two-fold—the immediate readers will be a local or regional audience, but the larger audience of disciplinary peers

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[50] See Mary Ellen Ellsworth's *A History of the Connecticut Academy of Arts and Sciences 1799-1999*. She explains that The Connecticut Academy of Arts and Sciences functioned similarly to other early scientific gatherings—it was comprised mainly of gentleman scholars who collected and shared work on local flora and fauna. Although members gathered and shared early pioneering data, however, they did not develop a systematic or thorough method of organizing and preserving it. This would seem to coincide with Gross' assessment that the shift in the nineteenth-century science was from one of gathering facts about the world to one of theorizing—the ontology of relationships. The Connecticut Academy existed in a continuum of such institutions in nineteenth-century America. Instead of a strong university system, like the European system, the American scientific community existed in a web of universities and smaller scientific institutions. The American scientific community had no identified center of authority for any given field; while knowledge certainly circulated widely (if slowly), there was no real institution that placed its stamp of approval on a scientist.

may not have easy access to the work. As Perelman and Olbrechts-Tyteca explain in *The New Rhetoric: A Treatise on Argumentation*, “we consider it preferable to define an audience, for the purposes of rhetoric, as the ensemble of those whom the speaker wishes to influence by his argumentation. Every speaker thinks, more or less consciously, of those he is seeking to persuade; these people form the audience to whom his speech is addressed” (19). Although Gibbs’ audience was other mathematicians, the members of the Connecticut Academy and his colleagues at Yale, the immediate readers of his first public work, could not follow the content of his argument.

Gibbs’ contemporaries and modern scientists consider “On the Equilibrium of Heterogeneous Substances” to be one of his most influential contributions to his field, and it came fairly early in his career. It was published in two sections in the October 1875-May 1876 edition and the May 1877-July 1878 edition of the *Transactions* (Gibbs, “Equilibrium” 55). In this groundbreaking work, what Raymond J. Seeger has called a *magnum opus*, Gibbs presents readers with an analytical paper that addresses the conditions for equilibrium and stability in a substance made of more than one component (77). Whereas earlier work in thermodynamics helped explain the work (through energy release) that could be gained from exploiting water steam in a closed system (a steam engine), Gibbs paper addressed “the private life of systems” of thermodynamics—the way a closed system of two or more components maintains equilibrium (Rukeyser 234). Gibbs addresses the ways in which matter changes from one phase state to another—from gas to liquid to solid—in a closed system (meaning a theoretical system removed from the real universe and all of its multitude of variables). Gibbs furthers this analysis by placing the three states within three different conditions of temperature, pressure, and chemical potential (the potential energy needed for a substance to change from one phase state to another).

Gibbs is credited with the discovery of chemical potential, which Rukeyser explains was the "Northwest Passage of this science; it was the link between classical thermodynamics and contemporary physical chemistry and electrochemistry" (237). It allowed Gibbs to create the Phase Rule, which describes the relationship used to determine the number of variable states in which a material can exist within a system, which, in turn, is necessary for fixing the thermodynamic state of a system into equilibrium. With this descriptive rule, certain variables in a system can become known quantities and can be used in future calculations without having to re-establish those quantities. Rukeyser explains:

> One of the immediate applications of these conditions [phase states under a given condition] of equilibrium, the state of maximum entropy, can be seen if we suppose that salt is sprinkled on some ice. Some of the salt dissolves, and some remains; some of the water evaporates, and some remains. We now have water and salt, our two components, in four phases—salt, salt water, water vapor, and ice. The Phase Rule gives us zero for the number of degrees of freedom [the number of states a system element could still potentially change into]. That is, equilibrium is assumed, and held. It is that which we count on when we use this mixture as a freezing mixture. We know from experiment that the temperature of this combination will automatically go to -22 degrees centigrade, and stay there. (239)

The process described above is made predictable and the energy involved and conditions exerting influence on the phase states are also predictable through the application of Gibbs' Phase Rule. Up until Gibbs' work, thermodynamics could measure the exchange and transformation of energy as either motion or heat; Gibbs introduced a language for measuring the underlying process of transformation (Rukeyser 239). He did this by measuring aspects of the change in phase states and representing those changes through graphical methods. While this description seems simple enough, the desire to create a language general enough to address the phase changes of matter under different conditions required that Gibbs' prose be dense and complex.

As important and groundbreaking as his work was, Gibbs had difficulty in gaining recognition. The audience for this work did not exist yet in Europe or America (Rukeyser 231). Furthermore, the financial limitations of its publication meant the abstract of the work was distributed more widely than the full papers. Gibbs' recorded correspondence from this time suggests that the early readers of the paper were from Europe and even then there was some difficulty in getting copies of the work on the continent. Lynde Phelps Wheeler cites a letter from Heinrich Hertz explaining he had trouble obtaining a copy of the paper because the "Cambridge Transactions are only with difficulty to be had here" (98). Of course, Hertz confuses the *Connecticut Transactions* with the *Cambridge Transactions*, but this highlights the difficulty in circulating scientific information among knowledgeable audiences in the 1800s. So, the difficulty that many in the United States had with his paper does not demonstrate an imaginative lack on their part so much as a lack in the institutional settings of professional science at the time.

Much of the official biographical information on the publication of Gibbs' early work by the Academy remarks upon the ignorance of the members about what they were reading and publishing. In her historical work, Mary Ellen Ellsworth reports that Gibbs' first public presentation of "The Principles of Thermodynamics as Determining Chemical Equilibrium" was accompanied by presentations on spectroscopic analysis of zodiacal light and another presentation on the size of the brain in tertiary animals. Ellsworth also explains that there was no immediate excited response to his presentation (83-84). The mix of presentations suggests that the initial scientific audience for his work was more accustomed to the natural sciences and not theoretical physical chemistry, and it hints at the type of rhetorical intervention he would have to enact. Whately reminds students, "When numerous and very mixed audience is to be addressed, much skill will be required in adapting Style, . . . and indeed the Argument also, and the whole structure of discourse, to the various minds which it is designed to impress" (258-259). Gibbs turns to this mutable sense of style in his work and often articulates his concern about the reception of his theoretical argument.

Gibbs' concern with methodologies of representation engages in the process of consciously crafting scientific communication for an audience of practitioners of experimental work or natural philosophy and not theoretical mathematicians. Peter Galison explains in *How Experiments End* that one of the main differences between experimental and theoretical cultures is the way in which their work is considered worthy of time. Galison notes an asymmetry between the two groups of scientists and accounts for it by arguing, "experimentalists express their public claims in a language that suggests experimental results are independent of the researcher's judgment, experience, or skills" (Galison 244). Experimentalists can rely upon the results of their experiments to vouch for the validity of their work, whereas the theorist relies on his or her argument. So, making claims about the efficacy of words was an important step in positing claims. Physical chemistry, as a discipline, was non-existent in the United States and in Europe during this period. General scientific work performed on the two continents differed widely; science in the US was concerned mainly with either the collecting activities of the natural sciences or the industrial applications of engineering while on the continent, and especially in Germany and France, scientific work was a much more theoretical endeavor.

Even though the mathematical bent of Gibbs' work was not part of the usual pattern of science that the Connecticut Academy's audience might be have expected, his work was intelligible to a larger international audience. As Gross et al explain, "The mathematical and chemical formulas [of the mid-nineteenth century] exist at a point in the scientific spectrum directly opposite the phenomenological descriptions of the early century. They are part of a shift toward explanation that is international in scope and that includes within its range sciences as diverse as geology, chemistry, physiology, biology, and physics" (*Communicating Science* 148). In "Graphical Methods in the Thermodynamics of Fluids," Gibbs comments upon the efficacy of his representation of information. But, his real concern about the clarity of representation is central to this earlier published work, which reflects the necessities of presenting his argument to a group he could not be sure would entirely understand it.

In his early work, Gibbs argues for a representational model for natural phenomena in general and not for one particular example of those phenomena. His interest in simplicity and brevity are analogous to Whately's admonition to his readers to use perspicuity and clarity for readers; both see these as organizational imperatives for the audience's experience of the writer's thinking. Gibbs' mathematical experience surely influenced his inclination to use geometric and graphical representation, but his audience is only familiar with this work in the field of mechanical engineering.[51] These elements also support a sense of disciplinary coherence within Gibbs' theories throughout his career that later scientists, like Donnan, respond to positively. The article is important for Gibbs' later theories of thermodynamics, because it is explicitly about representation, one of his main concerns in the field of thermodynamics: "The object of this article is to call attention to certain diagrams of different construction, which afford graphical methods coextensive in their applications with that in ordinary use, and preferable to it in many cases in respect of distinctness or of convenience" (Gibbs, "Graphical Methods" 41). Gibbs advocates for a particular graphical method using the rules of composition as outlined by Whately. This advocacy must, by definition, utilize tools not traditionally associated with mathematical reasoning. Gibbs advocates for his models on the grounds of their distinctness and convenience—both representational concerns. He hopes to persuade his audience of the usefulness of this method, which originated in mechanical engineering, for thermodynamic science. His continual mediations on what, at first glance, seem to be stylistic concerns, are central to conveying his thoughts to an audience unfamiliar with his work.

Apprehending Gibbs' Simplicity

For Gibbs, simplicity suggests how the larger argument coheres into a recognizable form; it is both about mathematical simplicity and the reader's ability to

[51] Raymond Seeger notes in his 1974 introduction to "Graphical Methods in the Thermodynamics of Fluids," that Gibbs draws upon his experience as a mechanical engineer to make use of graphical methods of representation in his initial study of thermodynamics and state changes (39).

apprehend that simplicity. Mathematical simplicity describes a tightly bound relationship between the natural world and a mathematical model, in which mathematical representation adequately predicts natural behavior with the fewest logical steps involved. Brian Rotman argues mathematical symbols are signs whose connections to the physical world are not pre-determined but semiotic and, thus, open to rhetorical interpretation (46-47). Gibbs repeatedly claims that his graphical models are both simple (in this mathematical sense) and simple to apprehend and understand. His argument is presented as prose and as mathematical symbols. In order to persuade his audience of the power of his mathematical argument, Gibbs must persuade through his prose argument; he must demonstrate his mathematical argument and explain its significance. This dual meaning for simplicity suggests that he is concerned with both mathematical coherence and argumentative coherence in his writing.

In mathematics, simplicity is a function of arrangement. Mathematical arguments are not just based on a priori factual claims animated through a series of true or false statements. For Gibbs, the representation of mathematical simplicity to his audience is that, and it is also about creating rhetorical simplicity in his argument. Beyond the act of arranging mathematical symbols, Gibbs deploys the concepts of simplicity to create audience member consent. He also deploys simplicity as an evaluate topoi to persuade his readers of the usefulness of his new representative model.[52] His use of both forms of simplicity—as central to mathematical reasoning and as evaluative topoi available to

[52] In “Rhetoric, Topoi, and Scientific Revolutions,” Kenneth S. Zagacki and William Keith argue that one of the key rhetorical exigencies that scientists respond to is the transformation of revolutionary knowledge into established knowledge (59). Gibbs uses “simplicity” to help this transformation in his work.

scientists is takes advantage of both the field of mathematics and the field of formal rhetorical studies.

For Gibbs, simplicity, as a function of both representation and presentation, is a primary concern in his argument. He explains in "Graphical Methods in Thermodynamic Fluids" his choice of method is "to be determined by considerations of *simplicity and convenience*" (my emphasis, Gibbs, "Graphical Methods" 49). Gibbs chooses the graphical method because it has the potential for simplicity and convenience, and it draws upon his experience in mechanical engineering—a similar graphical method was used in his dissertation work entitled "On the Form of the Teeth of Wheels in Spur Gearing."[53] His graduate thesis mapped the positions of points of contact on the surface of two gearwheels, and in the argument the gears becomes the basis of an analysis of changes in the states of substances. For Gibbs, simplicity and convenience are the intersection of his prior experience with mathematical engineering and the ease with which mathematics can present certain types of data. In an effort to persuade his audience of its efficacy, Gibbs veers away from mathematical models and describes the process in prose:

> The fact, that the different states of a fluid can be represented by the positions of a point in a plane, so that the ordinates shall represent the

[53] In his doctoral dissertation "On the Form of the Teeth of Wheels in Spur Gearing," J Willard Gibbs demonstrates an early interest in more theoretical work over the mechanical engineering work he studied. Indeed, his dissertation opens with the following sentence: "The investigations of the necessary relations between the surfaces of the teeth of wheels, in order that they may satisfy the various conditions of practical utility, is one of considerable practical importance, and is suggestive of considerable geometrical and kinematical propositions" (Gibbs 10). His commentators opine that the only continuity between Gibbs' early work seen here and his later work in thermodynamics is one that is theoretical – i.e. the mechanical method as cited by Everett Waters in his commentary of Gibbs' dissertation work (Waters 43). Here Waters almost in an accusing tone tells the reader that one should not bother reading this piece if one is not familiar with geometrical representation.

> temperatures, and the heat received or given out by the fluid shall be represented by the area bounded by the line representing the states through which the body passes, the ordinates drawn through the extreme points of this line, and the axis of the abscissas,--this fact, clumsy as its expression in words maybe, is one which presents a clear image to the eye, and which the mind can readily grasp and retain. ("Graphical Methods" 53)

He highlights the ease with which the mind will imagine both the graphical representation and the actual physical event. Although he does not mention simplicity by name here, it is present as the unspoken opposite of "clumsy." Gibbs argues that even though the reader must frame the image (there is no illustration in this section of the essay) it is easily comprehensible.

The imagination becomes increasingly important for Gibbs as he relies on the concept of simplicity in his work. This deliberate mediation on the efficacy of the model is analogous to Scottish New Rhetoric discussions of the imagination and "taste." Phil Dolph explains, "the imagination functions as the seat of taste and responds to certain qualities which may, apparently, appear in almost any idea" (106). Gibbs links simplicity with convenience and decouples it from language; in doing so, his work becomes something that transcends language (here presented as something that is inherently clumsy) to be experienced directly sans representation. In Gibbs' formulation, language is unable to represent the fit between the model and nature, but he consistently argues that understanding would be better if he and the audience adhered to the basic stylistic elements of representation like simplicity. It suggests that the structuring stylistic elements of Whately's rhetoric, which borrows from an epistemological-psychological model of the mind, is echoed throughout Gibbs' essay. These reverberations speak to the tenacity of this model of experience and rhetoric. Gibbs is pre-occupied throughout this paper with the concept of simplicity—not just as a way to describe his graphical approach but also as a way of advocating for good theoretical work and its representation. The essay has seven hundred equations and only sixteen small graphical representations scattered throughout the text on a total of six pages. These figures are then only used to illustrate very specific mathematical equations and not general aspects of this theory. He is aware of the difficulty that his audience will have with imagining the graphical representation that he is describing; nevertheless, he relies on the key aspects of imagination in his writing to engage with the audience to persuade them of the correctness of his argument.

Gibbs struggles to balance the presentation of mathematical equations with prose explanations of their functions and effects as he advocates for their efficacy in solving the problem of heterogeneous equilibrium. Relying heavily on prose to explain the mathematics, Gibbs advocates the efficacy of mathematical representation to a group unfamiliar with its work. In doing so, he attempts to connect with them on the level of imagination in order to advocate his theories. Whately advises the scientific writer to "excite interest," and here we see Gibbs attempting to do so. Gibbs is attempting to advocate for a mathematical theory through prose writing and many in his immediate audience can only understand the prose and not the mathematical formulas. Gibbs' continual return to "simplicity" is an attempt to use his rhetorical training to satisfy the argumentative demands of physical chemistry and the genre demands of the scientific article for an audience unfamiliar with the bulk of his mathematical argument. He accomplishes this feat by appealing to imagination over the use of language and does this through decrying the very medium of language he uses. Simplicity operates as the glue between philosophic commitments in scientific activity as well as the foundation for a rhetorical understanding of his argument. Thus, his argument becomes intelligible to a variety of audiences through an appeal to and inclusion of simplicity as an operative concept of perception.

Brevity, Mathematics, and Argument

In "Graphical Methods," Gibbs' representational strategy and the key to the success of his model hinges on the audience understanding his model as a series of points plotted on a plane, representing an infinitesimally small series of changes in order to create a record of imperceptible events: "Now if we associate a particular point in a plane with every separate state, of which the body is capable, in any continuous manner, so that states differing infinitely little are associated with points which are infinitely near each other, the points associated with states of equal volume will form lines" (Gibbs, "Graphical Methods" 43). Perspicuity, which Gibbs calls brevity, then, is a method by which he satisfies both the mathematical and rhetorical demands by shortening his complex reasoning into something useful for mathematicians and his audience.[54] As he sets his terms and outlines the basic functioning of this representational method, he clearly references concerns of ambiguity in his terminology and seeks at every turn to

[54] This facet of his writing is also considered to be one of the more vexing problems with reading his work. Martin Klein reports that many mathematicians, including Einstein, found his terse writing difficult. Klein attributes Gibbs' brevity to his lack of colleagues at Yale. Forced to work in relative disciplinary solitude, Gibbs would work out the problems of his work alone, and his writing reflected only the presentation of the completed idea rather than a series of articles working on a problem. Klein also reports that Gibbs rarely (if ever) shared his work in progress with his graduate students as well; he explains Gibbs was noted for being "of a retiring disposition" and not prone to discussing his work (150).

balance concerns with ambiguity with his interest in presenting a convenient form of representation.

For Gibbs, the pseudo-heuristic concepts simplicity and brevity often appear within the text as commentary on his presentation. This appearance suggests that providing his audience with insight into his deliberations over presentation of material supports a professional, scientific ethos that exceeds just the presentation of technical skill:

> For the sake of brevity, it will be convenient to use language which attributes to the diagram properties which belong to the associated states of the body. Thus it can give rise to no ambiguity, if we speak of the volume or the temperature of a point in the diagram, or of the work or heat of a line, instead of the volume or temperature of the body in the state associated with the point, or the work done or the heat received by the body in passing through the states associated with the points of the line. In like manner, also we may speak of the body moving along a line in the diagram, instead of passing through the series of states represented by the line. (Gibbs, "Graphical Methods" 44)

Gibbs invokes brevity to explain a choice in descriptive language. He explicitly acknowledges the representational function of his work and implicitly points his audience to an understanding of the writing tasks he undertakes on their behalf. Because Gibbs understands that the potential audience for this piece may not understand the representational connections he makes, he must include these deliberations in the prose in order to create an ethos that can demonstrate his faculty for judgment. What he describes above is a complex relationship between two representational systems. The diagrammatic system describes changes in volume or temperature, but these results, which are already inscribed in the language of the diagram, must be re-inscribed in prose.

Recognizing the possible resulting confusion from this double inscription, Gibbs resorts to calling on brevity as a reason for his representational choice.

Gibbs's representational concerns are almost exclusively about convenience, brevity, and simplicity. Brevity and simplicity help achieve "convenience," and they generate a sense of coherence in the argument. As Gibbs shortens long, complex terms, he hopes to demonstrate the efficacy of his argument. In the example above, he conducts an act of representational equivalence arguing that his method of representation will create a two dimensional graph representing a three dimensional change. Brevity erases the gap between the representation and the natural phenomena. By stating that brevity, an argumentative concern, is the reason for the shift in language, Gibbs can make the representative model stand for natural phenomena. Furthermore, he demonstrates the persuasive power of rhetorical argument—of appropriately ordering and representing the argument one needs to make.

Gibbs hopes to avoid the ambiguity that arises from using mechanical engineering imagery for thermodynamic theorizing. The mismatch between the Scottish New Rhetoric's (non) approach to mathematical demonstration and its requirement that rhetors engage the imagination combine in Gibbs' work, resulting in convoluted prose in an attempt to create rhetorical power through *insisting* on a clarity accessible only through imagination. The prose is most certainly not clear, but Gibbs insists that the ideas are clearly stated. In lieu of presenting page after page of mathematical formula, Gibbs is required to work in prose. He never quite feels comfortable with the medium's ability to describe his theoretical work and the power of mathematics. Regardless, he calls on brevity (or perspicuity) as a reason for abbreviating his argument and creating an ever increasing numbered list of formulas. Perspicuity is a function of rhetorical training and scientific necessity, and, as such, it shapes Gibbs' scientific discourse as he crafts a coherent argument that he argues is simple to apprehend even though so many found it difficult.

Gibbs' writing also demonstrates the difficulties faced by many theoretical scientists in communicating their work in the nineteenth century. As the nineteenth-century scientific rhetors theorized about abstract concepts, the scientific article reflected this by turning towards more abstract language and verb usage (Gross et al 123). Gibbs' scientific article, which describes the phase state changes of matter from gas to liquid to solid, argumentatively adheres to Scottish New Rhetoric standards of argumentative advocacy. He attempts to make his argument intelligible by moving the theoretical conversation between the world of the mechanical and the world of the theoretical to introduce the new concept of entropy in chemical systems. The states of transfer that he is attempting to describe and theorize are on an infinitely small level, inaccessible to the naked or aided eye. He describes a mechanical system of two processes—ones that retard motion like friction and ones that increase change like heat or energy. He goes on to illuminate what those forces look like in a mechanical system and then begins to explain the relationship between those forces in a chemical system:

> The condition which we have supposed is therefore sufficient for equilibrium, so far as the motion of masses and the transfer of heat are concerned [friction and the second law of the thermodynamics], but to show the same is true in regard to the motions of diffusion and chemical or molecular changes, when these can occur without being accompanied or followed by the motions of masses or the transfer of heat, we must recourse to considerations of a more general nature. (Gibbs, "Equilibrium" 59)

Gibbs is describing a mechanical construct that demonstrates a state of equilibrium between forces that retard work and forces that promote work. When matter changes state it does not exhibit the mechanical signs observable in heretofore-familiar systems; instead, Gibbs is required to resort to “considerations of a more general nature.” This is the first move from the mechanical world to the theoretical world in Gibbs’ work. The generality of Gibbs’ work is often cited as a key to its eventual adoption, and it is the underlying reasoning behind the use of mathematical models in scientific work. In effect, Gibbs is arguing for the adoption of his mathematical system through a more fundamental adoption of the efficacy of mathematics to solve this particular set of problems. The already agreed upon aesthetic components of mathematics are thus transferred to his overarching argument in this paper. Mathematics’ ability to shorten and to model is used synonymously with his own argument to suggest that he could more effectively eliminate his dense prose by substituting purer mathematical models. The small community of mechanical engineers in the United States would have understood his mathematics (to an extent) if not the thermodynamic implications.

Through generalizing and creating short equivalent terms, Gibbs explains the imperative for symbolic representation of lengthy and wordy terms. Brevity, as a tool for achieving simplicity, is achieved, in part, by nominalization. In “Things and Relations: Regrammaticising Experience as Technical Knowledge” M.A.K. Halliday explores how nominalization augments the discussion of abstract concepts; in particular, he argues that language is a theory of human experience (194). Gibbs often explains to the reader that he is doing things for “brevity’s sake” and nominalization helps him support this claim; he makes representative choices based on the possible experiences of his text. The arrangement of increasingly abstract expressions emphasizes the efficacy of Gibbs' mathematical intervention to simplify representation. He takes the complex idea of a substance and converts it to a series, represents the movement of that series in a mathematical formula. He then assigns an example number to the equation, so he can then make further statements by turning a complex function into a noun (the number). He can then make statements such as:

> Equations (19) and (20) express the conditions of thermal and mechanical equilibrium, viz, that the temperature and the pressure must be constant throughout the whole mass. In equations (21) we have the conditions characteristic of chemical equilibrium. If we call a quantity ux, as defined by such an equation as (12), the POTENTIAL for the substance Sx in the homogenous mass considered, these conditions may be expressed as follows:—
> *THE POTENTIAL FOR EACH COMPONENT SUBSTANCE MUST BE CONSTANT THROUGH THE WHOLE MASS*. (Gibbs, "Equilibrium" 65)

Complex statements are simplified and nominalized to such a degree that a very complex process becomes a noun inserted into a more familiar grammatical structure whereby it stands for a complex concept. The nominalization process is how Gibbs achieves brevity, which is (in part) the basis for his argument of simplicity. Brevity supports his inclusion of mathematics in that under the auspices of rhetorical brevity, he inserts mathematics-like notations into his sentences.

Gibbs' writing moves from the term to the example to another example to the general statement. In this manner, his rhetorical style enacts a type of simplification that is not an economy of style so much as it is a method of equivalence between a syntactically complex statement and a representative symbol placed within another complex statement. It may seem to reflect earlier rhetorical concerns of the Scottish New Rhetoric as taught in Whately's book, where he exhorts students to forego technical language and to simplify their writing for the audience, but it relies on a nuanced technical understanding of the mathematics involved and the chemical changes taking place. Gibbs emphasizes the final statement "The potential for each component substance must be constant through the whole mass" and simplifies several dense pages of mathematical demonstration. This general principle resulted from a lengthy mathematical demonstration, but this, not the mathematics, is what his contemporaries at Yale would have understood. His typographical emphasis underscores the importance that he places on such statements in making his overall argument, and it highlights the lingering presence of Scottish New Rhetoric imperatives in his supposedly mathematical project.

Gibbs insists on simplicity of understanding even though it does not exist for most of his audience, and, in doing so, he echoes standard advice found in Whately's text that explains that simplicity is always preferable when crafting an argument. This is not to say that Gibbs achieves simplicity in his argument, but that his continual discussion of it suggests that he understood the power of "simplicity" as a part of the style of argument. Indeed, as we saw in Whately's "Part III: Style," it is in the style of presentation that logical arguments are molded for consumption by the audience. And, as Einhorn argues, in Whately's text style is central to the project of crafting meaning for an audience. Gibbs takes many opportunities to try and convince his audience of the simplicity of his argument, only to demonstrate through the technical complexity of his mathematics that his work is far from simple. And, we must also remember that Gibbs is not only arguing for the usefulness of his mathematical formula but also for a still contested mode of understanding the natural world. Mathematical interventions into abstract and non-observable phenomena were only recently being adopted for widespread use in nineteenth-century science. All of these exigencies must be considered when thinking about the aesthetic claims Gibbs makes and the ultimate reception of his work.

Metaphor and "On the Equilibrium Of Heterogeneous Substances"

In his abstract for "On the Equilibrium of Heterogeneous Substances," Gibbs deftly repositions his work as central to the understanding of entropy in thermodynamic systems through the use of a metaphor that a scientist with a passing interest in the field would know—a permeable barrier separating two different states of matter similar to the image of Maxwell's Demon introduced to the scientific community by James Clerk Maxwell in his 1871 book *The Theory of Heat* (Everitt 74). Gibbs' abstract was published in the December 1878 volume of the *American Journal of Science* and ran for sixteen pages. In the abstract, he sought to maintain the same structure as the longer paper, using similar headings but providing truncated sections describing his theories. Abstracts were the primary genre for dissemination of scientific theories in the nineteenth century, and the formal aspects of the genre affect how a reader experiences the text. Articles of the seventeenth and eighteenth centuries were meant to be read from start to finish as opposed to the twentieth-century scientific articles, with headings and prescribed sections, meant to be skimmed and "mined" (Gross et al 42). In the nineteenth century, abstracts were still not formal elements of the longer paper, and they sometimes were still considered works that could be presented on their own (Gross et al 132). This seems to be the case with Gibbs' abstract, which lacks the complex mathematical equations found in the longer paper. Gone, too, are the sentences in which he assigns the mathematical equations reference numbers, which are, in turn, nominalized in succeeding sentences. Where possible, the abstract relies upon prose rather than equations, and the self-reflexive tendency to worry about issues of simplicity is absent.

Lacking the space to move through his mathematical formulas, Gibbs uses the image of a permeable diaphragm to illustrate his theory that restriction of free movement of substances will diminish the conditions for equilibrium. He argues:

> If we suppose two fluid masses to be separated by a diaphragm which is permeable to some of the component substances and not to others, of the conditions of equilibrium which have just been mentioned, those will subsist which relate to temperature and the potentials for the substances to which the diaphragm is permeable, but those relating to the potentials for the substances to which the diaphragm is impermeable will no longer be necessary. (Gibbs, "Abstract" 356)

This image of the permeable diaphragm is similar to the image of Maxwell's Demon wherein a demon sits between two containers filled with the same gas at the same temperature.[55] Gibbs' permeable diaphragm does not have the same image of the decision-making demon, but it does posit a discriminatory boundary he uses to delineate a conceptual space in which to deal with heterogeneous substances. Gibbs follows the prescriptions laid down by Whately to make his argument as intelligible as possible to a varied audience. The abstract would reach a larger audience, but it needed to rely less on his tools of brevity and arguments for simplicity; instead, it made use of the rhetorical tool of metaphor to illustrate the "tightness of fit" between his mathematical models and

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[55] In "Self-Reflexive Metaphors in Maxwell's Demon and Shannon's Choice," N. Katherine Hayles describes Maxwell's thought experiment. The demon operates a trap door between the two containers and sorts the faster moving molecules into one container. Eventually, one container will hold slower molecules and the other faster ones so that the demon decreases entropy in violation of the second law of thermodynamics, which states that in a closed system entropy increases towards a stable equilibrium (209-210).

physical reality. Using the metaphor heavily in the abstract underscores Gibbs' understanding of his possible audiences and the limitations of the medium in which he published.

The use of metaphorical devices is not new in scientific writing, but in this case, it demonstrates the writer's familiarity with the Scottish New Rhetoric, which favored making arguments from "direct experience" and "indirect experience" (Johnson, *Nineteenth-Century* 24). Whately's contribution to rhetorical practice is the restatement of style's importance in argumentation (Johnson, *Nineteenth-Century* 59), and Gibbs' reliance on the metaphor of a diaphragm to describe the action of matter's changing state reflects this imperative. The metaphor relates the abstract representative model to a common experiential image. In "Self-Reflexive Metaphors in Maxwell's Demon and Shannon's Choice," N. Katherine Hayles explains, "Heuristic fictions like Maxwell's Demon are like metaphors because they posit a relation between the fiction and the theory which gestures towards similarity" (210). The metaphor relates the abstract representative model to a common experiential image. The Scottish New Rhetoric's promotion of the "indirect experience" of metaphors and analogies as argumentative tools proves useful for Gibb's theoretical science. He creates the metaphorical image of the membrane in the longer articles: "As the equations of condition, of which we have made use, are such as always apply to matter enclosed in a rigid, impermeable, and non-conducting envelope, the particular conditions of equilibrium which we have found will always be sufficient for equilibrium" (Gibbs, "Equilibrium" 82). The image of the rigid envelope quickly gives way to the concept of a diaphragm. In the section of the longer article entitled "Effect of a Diaphragm (Equilibrium of Osmotic Forces)," Gibbs introduces the metaphor of the diaphragm, which represents the tension created by the meeting of osmotic forces:

> If the given mass, enclosed as before, is divided into two parts, each of which is homogenous and fluid, by a diaphragm which is capable of supporting an excess of pressure on either side, and is permeable to some of the components and impermeable to others, we shall have the equations of condition [temperature, pressure, and chemical potential]. ("Equilibrium" 83)

Gibbs illustrates the conditions under which his mathematical equations are useful by introducing his audience to the metaphor of a diaphragm. The diaphragm is a construct meant to illustrate a physical tension and not a static object between two states of being. The passage above illustrates the link between metaphorical demonstration and mathematical work.

Furthermore, Gibbs posits in the longer article this theoretical diaphragm as a perfect construct that allows "the passage of the components of fluids in certain proportions" (Gibbs, "Equilibrium" 84). Depending on the make up of fluids, the boundary will or will not allow a substance through. The diaphragm proposed by Gibbs is an organizational metaphor for conditions used to exclude certain actions from consideration, and it is presented as something borne out in the particulars during experimentation, an activity that Gibbs never took part in during his career. Gibbs' contemporaries were using mechanical models to represent and work with the quantities under investigation—volume, pressure, temperature, energy, and entropy—but he was interested in the representation of these phenomena, in order to represent entities that were not immediately accessible to human experience. The papers' and abstract's illustrative arguments constantly bridge the divide between the gross physical world and the world of infinitely small actions. In this case, the metaphor of the diaphragm helps bring those two worlds closer together.

Judging Scientific Labor: Between Theory and Industry

Scientific labor is judged by the new understanding it generates. The arguments crafted by theoretical scientists like Gibbs had far more cultural capital than would seem to be apparent for such esoteric material. Early theoretical scientific work in the United States seems to have been judged in part on the appearance of intellectual heft it brought to the debates in the states. The early theoreticians faced extremely difficult rhetorical situations, and their arguments for investigating theoretical work relied heavily on engaging with indirect values to argue for and demonstrate coherence. In general, the same reliance on rhetorically grounded concepts of simplicity and the use of metaphor were then evaluated as part of the overall argument. These elements of the argument point towards a tendency to expect coherence as an argumentative feature, and this feature is central to evaluative arguments about the larger cultural worth of the work. The evaluation of this work took the form of championing coherence in argument. Furthermore, this early theoretical work was already being compared to industrial applications. The aesthetic beauty of the coherence of the theories was judged against work with more immediate financial gain associated with it.

If, as noted at the beginning of this chapter, Gibbs felt his work did not value the time of his readers and if this article fell short in their argumentative simplicity and brevity, then what work did Gibbs consider successful? In 1888, Gibbs was asked to write the eulogy, a basic epideictic exercise, for Clausius, who first stated the second law of thermodynamics and introduced the term entropy. As expected for a notice in a publication intended for professional scientists, it mainly consisted of an overview of Clausius' theories with a brief sojourn into the history of study of gases as a way to contextualize Clausius' work in thermodynamics. In order to contextualize the study of thermodynamics, Gibbs claims that Clausius' initial interest in studying gaseous states was the latest iteration of the pursuit to articulate the kinetic theory of gases, its beginnings as a subject "lost in remote antiquity" ("Clausius" 265). Gibbs places the project on a historical timeline and firmly roots it in theoretical concerns rather than in industrial applications, demonstrating that thermodynamics started in the realm of the theoretical rather than the industrial. It wouldn't be until later in the 1800s and early 1900s that industrial practice would find financial gains in using this work. Gibbs ends the notice with: "But such work as that of Clausius is not measured by counting titles or pages. His true monument lies not on the shelves of libraries but in the thoughts of men and the history of more than one science" ("Clausius" 267). This monument comes from Clausius' ability to create order from chaos:

> The constructive power thus exhibited, this ability to bring order out of confusion, this breadth of view which could apprehend one truth without losing sight of another, this nice discrimination to separate truth from error, —these are the qualities which place the professor in the first rank of scientific men. (Gibbs, "Clausius" 263)

Other than his brief comments on his own writing, there are no records of Gibbs' thoughts on his own worth in the scientific pursuit of knowledge, but his recognition of Clausius' work in the field hinges on the rhetorical force of two central ideas—that the theorizing mind brings order out of chaos, and that its true benefit is not a tool or machine of industry.

Gibbs performed a similar duty for Hubert Anson Newton, a famous proponent of pure mathematics, when he died in 1896; it was published in the May 1897 edition of the *American Journal of Science*. Gibbs is very aware of the influence that culture has on scientific pursuits. While describing the course of Newton's career and his overarching interest in higher geometry and work in astronomy, Gibbs remarks:

> In the attention which has been paid to astronomy in this country we may recognize the history of the world repeating itself in a new country in respect to the order of the development of the sciences, or it maybe enough to say that the questions which nature forces on us are likely to get more attention in a new country and a bustling age, than those which a reflective mind puts itself, and the love of abstract truth which prompts to the construction of a system of doctrine, and the refined taste which is a critic of methods of demonstration, are matters of slow growth. At all events, when Professor Newton was entering upon his professorship, the study of the higher geometry was less consonant with the spirit of the age of this country than the pursuit of astronomical knowledge, and the latter sphere of activity soon engrossed his best efforts. ("Newton" 269)

Gibbs also venerates Newton's work in establishing law and order where others had not. To this end, he cites Professor Klein's "Lectures on Mathematics" delivered at the Chicago World's Fair before an audience of twenty mathematicians (Gibbs, "Newton" 281). In this lecture, Klein delineates three types of mathematicians—logicians, geometers, and formalists. Gibbs places Newton in to the class of geometers who created system of "abstract geometrical truth" ("Newton" 281-82). Like Clausius, and like Gibbs himself, Newton was among those scientists concerned with the truth that came from the creation of order out of chaos—out of creating systems to understand the facts of the world. Gibbs conceptualizes theoretical work as work—presentation and ordering—of the Scottish New Rhetoric. And, years later, F.G. Donnan will describe the value of Gibbs' work in a similar fashion—the ordered garden of abstract, theoretical knowledge.

The difference between theoretical and industrial science also shaped Gibbs' estimation of his own work as well. One year after publishing "On the Equilibrium of Heterogeneous Substances," on April 21, 1879, Gibbs was elected to the National Academy of Sciences, and in 1880 he was elected to American Academy of Arts and Sciences. In his acceptance letter to the American Academy of Arts and Sciences, he acknowledges, "This mark of approbation of my treatment of questions of thermodynamics is the more gratifying, as the value of theoretical investigation is more difficult to estimate than the results obtained in fields of labor" (Rptd. Wheeler 88-89). Gibbs distinguishes between fields of labor and theoretical investigation; the laboratory was the considered the pre-eminent place of scientific work at this time (Servos 144). He places his writing within a particular framework of theoretical investigation, which is not like experimental work in the laboratory. In effect, Gibbs highlights the differences between mental, theoretical work and physical work in the lab.

Despite the award, Gibbs' work was largely unrecognized in the United States during the 1880s due to differences in disciplinary knowledge. Physicists were the first group of scientists to take notice of Gibbs' work. Since they also dealt in mathematical formula, they shared the common language of Gibbs' theoretical work and may have best understood the difficulties in evaluating mental labor as opposed to physical labor in the lab. This difference between mental work and the physical work of the lab was mirrored in Gibbs' prose that is often dense and "requires unrelieved concentration of thought" (Wheeler 95).

However, by the time Gibbs' work was being widely praised, theoretical thermodynamics had been thoroughly adapted for use in industry, and his work was celebrated as theoretically imaginative but most valuable as the basis for industrial practice. In the 1928 "Willard Gibbs: An Appreciation," John Johnston replicated F.G. Donnan's speech, and cited Donnan's reference that Henry Adams once claimed that after Benjamin Franklin, Josiah Willard Gibbs was the greatest scientist ever produced in the United States (136). Johnston went on to agree with Donnan's assessment that it was through the sheer "force of his mind" that Gibbs was able to create such wonderful work. However, Johnston spent the rest of the article citing the industrial applications and celebrations of Gibbs' work. After several examples, Johnston claims: "[o]ther statements illustrating the economic importance of this abstruse imaginative investigation could readily be found; but they are unnecessary" (138). Here, we see the purest expression of the imagination's relationship to the industrial, practical sciences. After decades of obscurity, Gibbs' imagination was celebrated for its creation of a theoretical model that grounds industrial practice. Johnston concluded his "appreciation" by citing Gibbs' eulogy of Newton discussed above. In the repurposing the eulogy, Johnston stressed Gibbs' ability to create coherence and order out of chaos.

Coherence and Aesthetics in Scientific Rhetorical Labor

Nineteenth-century scientists, much like their counterparts today, were responsible for crafting convincing arguments and demonstrating their judgment for an audience. Creating coherence is the primary labor of theoretical scientists, and one that draws upon their ability to arrange materials in their arguments relying upon direct and indirect values of scientific practice. Theories are coherent narratives that have predictive power and are useful for understanding certain classes of problems. Simplicity and brevity were used to craft theoretical arguments and advocate for their acceptance; both of these rhetorical elements speak to the supposed coherence of the theory, but both elements are also functions of arrangement of argument. In this sense, we can argue that coherence is obtained through a strategic deployment of the elements of the article, paper, or treatise. The theory, as commonly understood by philosophers of science, never exists outside of language; it is always presented in a paper, an article, or a treatise—there are always prefatory materials, examples, etc. For all intents and purposes the theory is embedded within a written structure dependent on current understandings of what constitutes successful writing. For all of its mathematical complexity and (ultimately useful) ability to predict behavior of substances, Gibbs' theories exists within a matrix of language and representation produced in accordance with standard conceptions of writing practice at the time. The graphical representations were useful to the mathematician, but the written composition was also directed at the non-mathematicians that were also part of the scientific audience.

His now familiar calls for simplicity and brevity and their use as rhetorical tactics demonstrate that the scientific article underwent the changes that Gross outlines, but the rhetorical training of the rhetors in part inspired these changes. Finally, Gibbs uses metaphor as a rhetorical strategy as a result of his training in rhetorical practice. The three strategies deployed by Gibbs demonstrate the transitory nature of the scientific article as a rhetorical artifact, and they also highlight the need for the rhetor to demonstrate a scientific ethos. Without the standardized markers of the more modern scientific article, the nineteenth-century scientific rhetor needed to show the audience that he was capable of fulfilling the primary act of scientific judgment. Rhetorical education, as Kathryn Flannery has argued, replicates dominant values in a society; those who demonstrate facility with its tools are considered intelligible (7). Ideas of rhetorical taste are replicated in the form of scientific arguments and the articles and talks that made up the canon of scientific work in the nineteenth century. Gibbs use of simplicity, brevity, and the metaphor constitute the rhetorical work of ordering and presentation. Advocating for his mathematical model, Gibbs orders his thoughts and presents a cogent argument for his model. He later praises the same rhetorical labor in Clausius and Newton, and he conflates that labor with the labor of theorizing in pure mathematics. As Bitzer explains, the Scottish New Rhetoric argues that inferring and advocating—theorizing and presenting—are two different acts existing on a sliding scale of activity. In the case of nineteenth-century scientists making arguments for and evaluating the labor of their work, this scale can blur the lines between the lonely labor of theorizing and the public labor of presenting.

Far from wasting the time of his readers as he claims, Gibbs used the rhetorical tools available to him and his audience to construct a convincing argument for his mathematical models. Donnan's and others' valuation of his work demonstrate that the imagination of the scientific theorist seems to obtain in the well-ordered and imaginative mind of the rhetor, and the faculty psychology foundation of the Scottish New Rhetoric highlights the larger cultural valuation of this model for the mind. This is not to argue that Gibbs' mathematical work was somehow secondary to his argument; rather, the mathematical work had already been developed before the writing of the text, and, thus, the text argues for the adoption of this method. Gibbs' mental labor in this argument is really rhetorical work. His contemporaries and immediate successors saw in his written work, an arranged and compelling argument engaged with direct and indirect values of scientific practice—the elegance of a cohesive argument. And, as Donnan points out, this labor was central to the work of the experimentalist, whose laboratory products where often more valued than the theoretical underpinnings that made them possible.

Gibbs' work demonstrates how argument is central to the activity of theoretical scientists, and that argument is evaluated in ways that move beyond theoretical correctness to valuations of the mental labor of the scientist. These are important ways that scientific culture reflects on the products of scientific labor and the individuals involved in that process. Institutions of learning and the learned are necessary for the production and dissemination of new ideas, but formal rhetoric matters as well when crafting scientific arguments. Ideas alone do not command assent. To call Gibbs' an "imaginative" genius suggests that there is someone qualified to make this evaluation, but by the admission of the committee who was tasked with determining whether or not to publish his work, there did not seem to be anyone immediately present who could confirm the scientific and mathematical validity of his work. From his vantage point, almost 50 years later, Donnan can look back and see the uses of Gibbs' theories, the ways in which chemistry and physics equally benefited from his work, but no one can claim that this was an operative concern for people who had neither the benefit of historical hindsight nor the specialized knowledge to understand the work.

The two evaluations of his writing described in the beginning of this chapter shed some light on different aspects of Gibbs labor as a scientist. Donnan's nod towards the imagination demonstrates the ways in which Gibbs' theoretical work is valued as an imaginative act with arrangement at the center of its activity; indeed, the garden has long been considered the image of ordered nature in literature and cultural imagination. Gibb's critique of his own writing suggests a critical link between the ways in which scientific arguments are evaluated as arguments and the ways in which the Scottish New Rhetoric enumerated rules for evaluating the efficacy of an argument. These rules, it turn, support aesthetic evaluations of the scientific labor of argument and an estimation of the ethos of the writer. Gibbs was clearly concerned with presentation arrangement of his theoretical work; the ways in which he arranged the articles' content and his presentation of theories, examples, and analogies were the driving force behind the consent his arguments demanded. Lacking a shared lexicon of discipline specific terminology, scientists fell back on other shared values deciding whether or not to undertake the expensive enterprise of publishing and disseminating his work. Once it was established in the larger world, scientists with discipline specific knowledge could begin to judge the accuracy of his work. That fact notwithstanding, the non-scientific shared values of argumentation seemed to have been a powerful factor in Gibbs' construction of his work, but it is even more important for placing his work into a larger context of a culture of science that values something more than the theoretical efficacy of abstract, scientific labor.

CHAPTER 4

IMAGINATION AND ERROR: HENRY ROWLAND THE IDEA OF THE PHYSICIST

[I]t is certainly a wonderful feat of human reason and imagination that we know as much as we do at present.

--Henry Rowland, "The Highest Aim of the Physicist" delivered on October 28, 1899

Let the student be brought face to face with nature: let him exercise his reason with respect to the simplest physical phenomenon and then, in the laboratory, put his opinions to the test; the result is invariably humility, for he finds that nature has laws which must be discovered by labor and toil and not by wild flights of the imagination and scintillations of so-called genius.

--Henry Rowland, "The Physical Laboratory in Modern Education" delivered on February 22, 1886

The experiments described in this paper were made at such odd times as I could command . . .; hence I have not been so careful to guard against this error as I shall be in the future.

--Henry Rowland, "On the Magnetic Permeability and Maximum Magnetism of Nickel and Cobalt" published in *Philosophical Magazine* in 1873

Imagining a Rhetorical Response to Scientific Practice

Imagination and reason are fundamentally dichotomous terms in scientific practice, and their relationship affects conceptions of scientific practice and authority. The divide between the two seems to be vast—the one term suggests unfettered, extrapolation and wild flights of fantasy that can be fruitful at times; the other term suggests a methodical and trusted application of accepted practice and knowledge to a problem. The history of science is full of stories of an imaginative and inventive scientist approaching a problem from a new direction resulting in a revolutionary, or at least useful, solution to a particular problem. However, the tension between the imagination and reason defines an aesthetics of scientific practice; this tension highlights the connection between the form of a scientific argument and the driving force behind it.

An aesthetics of science must satisfy both the imagination and the reason; therefore, accuracy is a central aspect to an aesthetics of science because the imaginative answer must also be precise—it must be useful. An aesthetics of accuracy would be founded on the ability to identify the location and shape of an error and then articulate how it deviates from an accurate assessment, and this activity hinges on the technical judgment of the individual; the perception of the judgment informs the perception of the scientist's ethos and speaks to extra-empirical values of scientific practice. In order to solve a problem through scientific practice, the individual must define the problem and the approach to it; an audience's willingness to agree with the definition and approach to a problem is grounded in acceptance of the individual's scientific ethos. In order to call the problem to the community's attention and suggest a solution, the scientist must conform to a standard of practice that is both imaginative and reasonable. The solution must be imaginative enough to flexibly address a problem and reasonable enough to offer solutions that follow established scientific practice.[56] The balance between the

[56] See Peter Dear's *The Intelligibility of the Nature*. He argues that changes in scientific practice in the late-seventeenth and eighteenth century from one interested in describing the natural world to one interested in instrumentality created a "hybrid" understanding of the practice (11). As this hybrid practice was refined through the application of ever more precise formulas and measuring devices, there arose new value structures and new formulations of scientific ethos to best take advantage of and conform to those values.

imagination and the reason supports a scientific ethos authorized to make aesthetic judgments.

The rhetorical power of aesthetic judgment lies in the representation of a flexible and useful practice expressed as scientific ethos. To possess imagination but no reason renders the scientist unreliable and unable to produce scientific knowledge; to possess reason and no imagination, reduces the scientist to no more than a reliable technician who does not add to the stock of knowledge about the world. Citing Rollo Mayo, John Patton explains that creativity in rhetoric is always a matter of an "encounter" between the rhetor and the world where "'[a]n encounter is always a meeting of two poles,' the 'subjective pole' comprised of 'the conscious person in the creative act itself' and the 'objective pole' . . . i.e. 'the pattern of meaningful relations in which a person exists and in the design of which he or she participates'" (48). The relationship between these two poles is constantly negotiated in scientific practice through rhetoric.

A scientific ethos composed, in part, of an aesthetic sensibility oriented towards accuracy must be based on an understanding of the imagination as a necessary faculty for performing useful work in scientific inquiry. The imagination, or creativity, must be constantly balanced with factual data and patterns of experimental and instrumental practice. The ability to balance these two poles is central to creating and maintaining a scientific ethos capable of communicating with an audience. Alan Gross sees these two poles as being in a "dialectical contest" between "authority and its values" and "innovative initiatives without which no scientist is rewarded" (*Starring* 26). And, balancing the two poles is crucial to understanding how scientists have the standing to make aesthetic claims alongside statements about factual data.

In the early decades of modern physics, scientists were beginning to answer complicated questions of theoretical importance through new measuring instruments and theoretical models—working to adapt older knowledge to newer problems. The discipline was young, it required expensive equipment to test a hypothesis, and the results were only verifiable by other experts. As a field of research, physics required technical and theoretical knowledge that few researchers possessed. Furthermore, the results of laboring in this field were not often very valuable commercially. Early physicists needed to define themselves within this evolving exigence, and many did so by creating an ethos of scientific activity that was at once rigorous and flexible, reasonable and imaginative. In doing so, they addressed the concerns and values of multiple audiences—those within the discipline and those that funded and supported the discipline through support of the sciences in the university.

Often called the father of modern physics in America, Henry Augustus Rowland (November 27, 1848-April 16, 1901) was responsible for many of the modern advances in spectroscopy and measurement of magnetism and heat. His precision work in physics has interested scholars for some time, and his famous speech "A Plea for Pure Science" is cited from time to time in histories of nineteenth-century scientific culture in America. In Rowland's speeches, the tension between imagination and reason explicitly highlights the particular difficulties physicists had in generating appropriate ethos in their emerging discipline in the 1800s. His repeated calls for better funding of the discipline and proper training of physicists plays on the image of the imaginative researcher who unfailingly strives for logical reason in his approach. The expression of these values was a response to pressures within the field to develop and maintain the rigor of instrumental practice and balance that with the values of an imaginative practice.

In his scientific articles, Rowland invoked the twinned topoi of error and accuracy to generate a scientific ethos that was at once imaginative and reasonable. These two terms recurred in his speeches and his scientific writing, and they are central to understanding his rhetorical response to the problem of an imaginative scientific ethos in a rigorous scientific practice. For Rowland, imagination was not separate from accurate work; it was central to addressing issues of accuracy and error in laboratory work, and an ethos constructed (in part) of imagination was key to constructing a scientific ethos that could fruitfully address the topoi of accuracy and error in the course of scientific argument. In *The Scientific Imagination*, Gerald Holton argues that thematic analysis of scientific imagination allows for a "discernment of some constancies and continuities in the development of science, of relatively stable structures" (ix). In particular, he notes that there are often stable couplings of antithetical pairs of themata related "to the dialectical nature of science as a public, consensus-seeking activity" (Holton 10). In terms more familiar to rhetoricians, these themata are similar to topoi, the stuff of arguments and the form of those arguments (Lanham 152). Topoi are central to scientific arguments, and evaluative topoi are some of the most common found in scientific discourse.

Extending Holton's philosophical inquiry of themata's role to scientific discourse allows rhetoricians to understand the complex relationship between evaluative topoi and the rhetor in rhetorical situations. In particular, the evaluative topoi of error and accuracy exist in relationship to one another, and invoking one always invokes the other. This dual invocation responds to particular exigencies of a theory or experiment and posits the rhetor's competence to respond to these exigencies. To recognize error is to also state that you have a response to it. In scientific rhetoric, the ethos of the scientist is tightly bound with his or her ability to respond to these exigencies. Patton argues, "[W]hen rhetorical discourse develops, it can be said to do so in relation to some set of events or experiences capable of positive modification through the assistance of discourse" (44). In nineteenth-century physics, error and accuracy were primary topoi used to evaluate interactions with the world. The evaluative topoi of error and accuracy were the first step in making a modification to a particular relationship on the part of the scientist.

Crucial to understanding the rhetorical relationship between imagination and the topoi of error and accuracy in Rowland's writing is an understanding of the formal rhetorical training he experienced as an undergraduate at Rensselaer Polytechnic Institute (RPI). During his formative years at the school, he read and used as a course text George Payn Quackenbos' *Advanced Course of Composition and Rhetoric: A Series of Practical Lessons on the Origin, History, and Peculiarities of the English Language*. By synthesizing the work of George Campbell and Hugh Blair, this text introduced students to a critical understanding of the importance of taste and imagination in the formulation of arguments; Quackenbos' text presents both terms as central to judgment—itself a main component of scientific ethos. In particular, Quackenbos' formulation of imagination is echoed in Rowland's construction of scientific imagination, so an understanding of the Scottish New Rhetoric's formulation of this faculty would have informed the then common investigation of this concept. Quackenbos' recapitulation of Blair and Campbell instructed students on the function of imagination in argument, and Rowland's addresses suggest he drew from this instruction to formulate an appropriate critical stance towards judgment as a primary component of scientific ethos.

An aesthetics of science can be a powerful way to support the rhetorical work of making arguments, but it must also support the larger project of scientific inquiry. In order to construct a scientific ethos that can take advantage of the powerful extra-empirical values associated with an aesthetics of science, the scientific rhetor must address concerns over his or her ability to satisfy the technical goals of scientific inquiry while still being able to address extra-empirical values. To do this, this ethos must be perceived as rigorous and inventive—claims must be couched within known theories and also extend theoretical knowledge. For Rowland, the foundation of a useful scientific ethos is imagination. As a physicist, he spent his career attempting to produce the most accurate, error-free results in his experiments, and the motivation for his experimental practice was to produce measuring devices capable of producing incredibly accurate results. Constructing an ethos legible to both experts and lay people required he borrow the concept of imagination as a way to explain the basis for understanding scientific practice that could both satisfy the requirements of rigorous scientific inquiry and be inventive enough produce new theoretical knowledge.

This chapter shows how Rowland's constructed himself as a creative, imaginative scientist who regulates his mind to present an ethos of scientific behavior necessary to support the use of evaluative topoi such as accuracy and error. This exploration will illuminate the relationship between the scientist who is ready to perceive extra-empirical values and the scientist who can best deploy this ability in more field specific ways. There are two classes of Rowland's texts this chapter analyzes. The first will be

Rowland's public speeches, which articulate his arguments for the centrality of imagination in the critical practice of the scientist. The second class of texts represents his scientific writing, which use the evaluative topoi of error and accuracy as starting points. I first outline a brief history of Rowland and his work in order to contextualize his interest in constructing an imaginative scientific ethos. I then review George Payn Quackenbos' formulation of imagination and taste as crucial faculties for a rhetor's understanding of himself and argument. After a reading of the three public addresses concerning imaginative practice and the scientist Rowland delivered during his career, I will explicate the importance of evaluative topoi for an understanding of ethos in scientific argument. I will then expand on the meanings of error and accuracy as evaluative terms in Rowland's scientific practice to demonstrate how the use of these topoi is a precursor to a particular type of scientific ethos grounded in imagination. Finally, the chapter will end its analysis with a reading of two early articles by Rowland where he uses the evaluative topoi of error and accuracy.

By proceeding in this manner, I hope to explicate the connections between a rhetorical understanding of imagination and the creation of scientific ethos in response to disciplinary concerns. Scientific work is predicated on addressing questions in a methodologically appropriate way, and evaluative topoi are a necessary part of demonstrating the rhetor's ability to act in accordance with those methodologies. These approaches are, in turn, deemed aesthetically pleasing if they can adequately address the exigencies of error and accuracy. The authority to make aesthetic judgments is drawn from the ability to assess issues of accuracy and error. This ability, in turn, was grounded in discussions of aesthetics in rhetoric. The material for this response may have originated in rhetorical texts as well as in philosophical treatises. This point is an important distinction because it would demonstrate how the extra-empirical values of aesthetics are undergirded by values legible to multiple audiences. Like the concept of "simplicity," these evaluative topoi have substantial links to the philosophy of science, but they are by necessity rhetorical elements of an argument. They help articulate an ethos for scientific practice that is legitimate for scientific audiences as well as non-scientific audiences.

Articulating the value of theory and practice or describing the natural world and creating machines to measure it was an important step in grounding the emerging discipline of physics. Rowland was also responding to a funding environment that he felt was consistently hostile to the needs of physicists. In linking the imperatives of an earlier Natural Philosophy to the financial demands of funding for physics in the modern university, Rowland harnessed the wonder of natural philosophy to the instrumentally centrist manipulation of physical phenomena, so that the mind that was flexible enough to notice the beauty in nature could also be expert in instrumentation and measurement. Whereas history of science scholars view Rowland's concern with accuracy and error reflecting the demanding nature of physics as a practice, his attention to these topoi were central to his creation of a scientific ethos perceived capable enough to bridge the new-found divide between older disciplines and the emerging discipline of physics.

The elusiveness of the aesthetic experience in science suggests that it is ephemeral because it is bound within a community practice of communication that values the instrumentality of accuracy. Community standards dictated what would be considered an aesthetic experience and what would not be considered one. Although Rowland never expressly discussed a standard description for aesthetic experiences in his writing, he proffered a standard of imaginative attitude that the scientist must take towards his work. Furthermore, this scientist, unlike his practical counterpart, must approach his subject in a flexible manner. As Rowland explained in "The Highest Aim of the Physicist," "[I]t is certainly a wonderful feat of human reason and imagination that we know as much as we do at present" (672). The balance between these two attributes forms the basis for all evaluative judgments of the scientist. And as Rowland pointed out later in the same speech, these judgments are only important if they are shared with others. Through writing, the scientist can communicate relevant values by demonstrating his ability to construct arguments that generates new approaches through the use of prior knowledge.

Henry Augustus Rowland: Between Two Worlds

Henry Augustus Rowland was an American physicist and the first chair of the Physics Department at Johns Hopkins University in Baltimore, Maryland. Historians consider him to be one of the three central figures in nineteenth-century American physics; his contemporaries and historians have described him as a demanding researcher and thinker. Best known for his wide-ranging research in electromagnetism, heat, and light, he tirelessly sought after perfection and accuracy in his theoretical work through his laboratory equipment, which helped create the precise measurements used in his mathematical calculations. His career-long interest in experimental equipment and practice was apparent early in his life, and his subsequent training in civil engineering at RPI honed that interest into a laboratory practice and philosophical outlook on science that stressed research-oriented work rather than commercial inventions.

Rowland often referred to himself as a man between fields, and it was this sense of his relationship to the field of physics that drove him to be an exacting and tireless laboratory researcher.[57] However, his relationship to the field was not unique. George Sweetnam argues in “Precision Implemented: Henry Rowland, The Concave Diffraction Grating, and The Analysis of Light,” that Rowland’s combination of scientist and mechanic was typical of emerging disciplines in the nineteenth century like physics and astrophysics, which were reliant on machines and mathematical equations to perform their work (285). Indeed, in his commemorative address for Rowland, Thomas C. Mendenhall remarks that Rowland could have been a successful engineer or inventor if he had so chosen.[58] Furthermore, Edwin Layton details how the “mirror-image” relationship between research and technology in the nineteenth century explains the story of how Rowland discovered a method to significantly improve the efficiency of the electric dynamo, but how he “missed the significance of his discovery because he was looking for a law of nature, not a design principle” (226). Much of his success as a professor and inventor of scientific instrumentation sprang from the duel nature of Rowland’s professional interests and capabilities, but it also exemplified a unique moment in American scientific history.

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[57] See John David Miller’s dissertation “Henry Augustus Rowland and His Electromagnetic Researches” for a discussion on Rowland’s laboratory practice (14).

[58] See Thomas C. Mendenhall’s “Henry A. Rowland: Commemorative Address.” He explains, “Rowland’s interest in applied science cannot be passed over, for it was constantly showing itself, often, perhaps, unbidden, an unconscious bursting forth of that strong engineering instinct which was born in him, to which he often referred in familiar discourse, and which would unquestionably have brought him great success and distinction had he allowed it to direct the course of his life” (Mendenhall 10).

Rowland's hybrid nature as a scientist was a result of his personality and the education he received. His educational history skews towards the technical, and this technical education would seem to support the view that he disliked the humanities.[59] Rowland's interest in mechanical and scientific investigation ran counter to his family's plans for him. Like Josiah Willard Gibbs, Rowland was groomed from an early age to follow in the footsteps of his father, a minister (Rezneck 156). Rowland's mother hoped that he would attend Yale University. However, his early interest in experimental science and his long-standing dislike for Latin pointed him towards a different path than his father's. In 1866 after spending a year at Andover Academy, he began his studies at RPI, where he was given free rein to investigate natural phenomena in pursuit of his degree in Civil Engineering, a career he would pursue briefly until he could secure a position teaching and researching at a university.[60] Due to the financial problems of his widowed mother, he spent a short time in 1868-1869 at the Sheffield Scientific School at Yale, but returned to Rensselaer and graduated in 1870 with a degree in Civil Engineering.

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[59] For more on Rowland's stance on the humanities, see Samuel Rezneck's "The Education of an American Scientist: H.A. Rowland 1848-1901." He recounts a series of letters home where Rowland despaired at his time at Andover Academy in Massachusetts, which he attended in 1865. He writes: "I do not study anything but Latin, which we have twice a day . . . We go only to the recitations and then come back to our rooms. It is horrible. Ask mother if she won't please take me home again, for I feel I can never get on here." He later wrote, "I never expect to come here again. Why, mother, I could not stand it." (156). See also Miller's dissertation "Henry Augustus Rowland and His Electromagnetic Researches." In it, he relates another story whereby Rowland was discouraged in taking any interest the humanities. After completing his exams and being advanced to the second section at RPI, he began to study philosophy, but he was less than pleased with his instructor, whom he complained "does not try any experiments or do anything to make it interesting to us" (Miller 12).

[60] See Herbert Winnick's " A Reconsideration of Henry A. Rowland—the Man" for an explanation of how Rowland's intense interest in scientific research at university reflected a personality interested in more than just scientific advancement (23).

Although his work at RPI was focused in an area more suitable to working in the field than the laboratory, Rowland vigorously followed his own research agenda, which turned out to be closer to his eventual career as a research physicist.

Rowland's career was defined by his preference for laboratory work, what was called "pure science," but this preference for pure science came at a financial cost that he recognized throughout his life. Rezneck notes several examples where Rowland demonstrated his preference to spend money on experimental apparatus rather than other entertainments. For instance, Rezneck reports, Rowland asked for a new screw apparatus for his birthday, and another time, he wrote home to ask his mother for $200 to secure a patent on an automated telegraph machine of his own design (157). Mendenhall explains that Rowland's interest in scientific apparatus started early in his life and describes a boy interested in "chemical experiments, glass-blowing and other similar occupations" and whose "spare change was invested in copper wire . . . and his first five-dollar bill brought him . . . a small galvanic battery" (11). This early interest in scientific apparatus seems to have informed young Rowland's decision to enter into a career as a scientist. At the age of 20, he wrote his mother a letter that highlights his approach to the relationship between scientific practice and financial reward: "I intend to devote myself hereafter entirely to science. If she give me wealth I will receive it as if coming from a friend, but if not I will not murmur" (qtd. in Rezneck 159). Although, Rowland did not "murmur" for better financial situations for himself, he was a vocal proponent for funding for physics and other sciences that lacked immediately commercial uses.

In his later years and due to declining health and his new family, Rowland would engage in a flurry of patent activity. In the 1890s, he became interested in securing his family's financial footing, but he never pursued these activities with the same conviction as he did his scientific, experimental work. However, this apparent lack of concern for money did not extend to funding for his research. If Rowland could not be wealthy from his scientific pursuits, he felt they should at least be well funded. After spending his first year after graduating from RPI as a railroad surveyor, he obtained a position as an instructor in Physics at the College of Wooster in Ohio. Unfortunately for Rowland, the administration felt he spent too much money on scientific apparatus, and he left (Sweetnam, *Light* 4). He returned to RPI as an instructor and then assistant professor in Physics. Sweetnam explains that Rowland's contract with RPI guaranteed increased funding for experimental apparatus in lieu of a higher salary, but when the Institute failed to deliver the funds, Rowland demanded a higher salary, presumably to purchase the equipment himself (*Light* 4). Even though Rensselaer was far from antagonistic to scientific research, Rowland felt it was not supporting laboratory research in an appropriate manner, and he contacted the University of Pennsylvania in hopes of obtaining a position there that would secure more favorable funding for his experimental research (Sweetnam, *Light* 4). Rowland's dissatisfaction with the funding of his research set the stage for his move to Johns Hopkins University in 1875. It was there that he hoped to find a stable and suitable stream of funding for his complex and precise apparatus.

In 1875, Daniel Coit Gilman offered Rowland a position at Johns Hopkins because of Rowland's growing reputation for ingenuity and scientific genius.[61] Indeed, if Rowland eschewed financial success through his scientific work, he did seem to aspire to fame through his research. Mendenhall notes, "In April 1875, Rowland wrote, 'It will not be very long before my reputation reaches this country'" (14). Indeed, the paper that Rowland celebrated in the quote above was "On Magnetic Permeability and the Maximum of Magnetism of Iron, Steel, and Nickel" which was first rejected by the editors at *The American Journal of Science* at Yale.[62] It wasn't until Rowland sent it overseas to James Clerk Maxwell that the article was published in the British *Philosophical Magazine*. Shortly after its publication in England, American publishers were asking Rowland for permission to reprint the abstract in their journals as well. The subsequent fame and recognition that accompanied the publication of the article and, more importantly, the championing of Rowland by Maxwell, was the driving force behind his growing fame at home. Gilman, impressed by his recent publication and growing reputation for producing high quality experimental research, offered Rowland a position at Johns Hopkins University as Chair of the Physics Department.

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[61] See John David Miller's dissertation "Henry Augustus Rowland and His Electromagnetic Researches" pages 80-81 for more reports on the international reaction to Rowland's work.

[62] In particular, Sweetnam suggests that it was the incomprehension of American scientists in the face of his exacting mathematics that kept Rowland from publishing earlier in the United States. Ultimately, Sweetnam argues, it took Maxwell's mathematical acumen to notice Rowland's work and publish it in the *Philosophical Magazine* (*Light* 5).

Rowland's appointment would not start until 1876, and Gilman authorized Rowland to travel to Europe and work in laboratories in Germany and France. While studying in Europe, Rowland spent a reported $6,429 on experimental equipment that Gilman authorized to be reimbursed (Sweetnam, *Light* 7). Although Gilman enthusiastically supported Rowland's experimental practice in the beginning, their professional relationship would be strained in later years due to Rowland's steady demands for ever higher levels of funding for experimental apparatus.[63] Eventually, this would culminate in a dispute over the financial state of affairs surrounding Rowland's diffraction grating, his most famous and arguably most lucrative invention.[64] The ever-expanding facilities that Rowland required were expensive, and he and Gilman argued on several occasions over the prohibitive cost of manufacturing the gratings.[65] More aggravating for Gilman was the fact that, despite having a worldwide monopoly on high quality gratings, Rowland refused to charge prices reflecting that fact. In short, Johns

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[63] This is not to suggest that their personal relationship was permanently hurt. In his 1906 memoir *The Launching of a University*, Gilman heaps praise upon Rowland's scientific work. In particular, he gleefully cites an 1882 letter from Professor John Trowbridge of Harvard. It recounts a meeting in Europe where Rowland shared the results of his gratings with an international group of physicists: "Rowland . . . showed them [the physicists] his photographs and gratings. It is needless to say they were astonished. . . . The Germans spread their palms, looked as if they wished they had ventral fins and tails to express their sentiments" (Gilman, *The Launching of a University* 73).

[64] See George Sweetnam's "Precision Implemented: Henry Rowland, the Concave Diffraction Grating, and the Analysis of Light" for a lengthy discussion on the diffraction grating and its production.

[65] In "Precision Implemented," Sweetnam explains that Rowland frequently argued with Gilman over the necessity of employing a person to specifically tend the production machine. Furthermore, Gilman was unhappy with the fact that the whole operation ran at a constant deficit—once for nine years straight (Sweetnam, "Precision" 293).

Hopkins was losing money on the production and sale of diffraction gratings when they could easily have been making a profit. To these complaints, Rowland invariably responded that what the university was losing in income it was making up with reputation. He explained that every experiment using the gratings would result in a publication mentioning the university's role in producing the devices (Sweetnam, "Precision" 293). Like his earlier declarations that configured the relationship between science and money as an either/or relationship, Rowland articulates a similar conceptual framework for his mechanically inclined work. He also seemed to equate it with the personal fame that he sought as well. His gratings were sought throughout the world, and he clearly relished the envy of other scientists.

Rowland placed his commitment to research accuracy over profits, and these commitments were reflected in the scientific ethos that he created in his writing. Rowland was dedicated to an ideal of scientific practice that pitted the experimentalist against the industrial scientist. Furthermore, his thinking regarding the state of his discipline in relation to the university clearly demonstrates his understanding of the financial repercussions for his field when refusing to sell the diffraction gratings. And as Sweetnam argues, his dedication to his research displayed a dedication to a "style" of science that was as interested in how one obtained results as well as the results one obtained during the course of research (*Light* 137). These historical elements are important components for understanding his work, but he was also invested in generating an appropriate ethos in his writing as well. Furthermore, his speeches suggest that he was interested in codifying the standards for scientific ethos within his discipline.

Rowland's allegiance to "pure science" was very real and well documented, and I suggest that a better understanding of his scientific ethos can come from understanding the links he makes between imaginative work and the ability to address the topoi of error and accuracy. These connected concepts inform his formulation of a scientific ethos best suited to the demands of the discipline. The following addresses and articles come from one man's pen but reflect growing institutional and cultural approaches to conceptualizing scientific practice in the nineteenth century. Above all, buried in Rowland's writings are important clues as to how the scientist managed his response to the aesthetic experience of practicing scientific research in a modern laboratory.

As a towering figure in nineteenth-century American physics, it is impossible to ignore Rowland's influence on both the knowledge of the field and the way in which the burgeoning community of physicists thought of their activity. Rowland argues that the proper experimental scientist should balance the imaginative while adhering to practices of proper data collection. We can surmise that Quackenbos' rhetoric textbook would have been one of the only texts he came into contact with during his undergraduate years that expressed any position on aesthetic appreciation and the role of imagination in critique. Of course, Rowland was most interested in accuracy and error in his work and the work of others, but these are evaluative topoi that make sense within a framework of critique that is more akin to the rhetorical concept of imagination and taste. However, Rowland's focus on accuracy and error are grounded a scientific ethos reliant upon scientific imagination. A study of Quackenbos' formulation of imagination and taste as critical faculties will highlight how nineteenth-century rhetors were instructed how to foster this skill and to what ends.

George Payn Quackenbos' Imaginative Rhetor

George Payn Quackenbos was a widely published writer of rhetoric handbooks and textbooks. One of his most adopted books *Advanced Course of Composition and Rhetoric: A Series of Practical Lessons on the Origin, History, and Peculiarities of the English Language* (1865) underwent several printings and was used throughout the United States.[66] Although he is an understudied and overlooked writer of composition textbooks, the adoption of his book in colleges contributed to a larger cultural understanding of argument and rhetoric in the nineteenth century; its wide distribution alone suggests that university students would have been familiar with the text.[67]

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[66] The choice of Quackenbos' text could not have been more in-line with the task oriented, lyceum model under which Rensselaer Polytechnic Institute was founded and ran. The course of study for civil engineers highlighted its very practical and nationalistic bent. In his chapter detailing the founding of the Civil Engineering Department at RPI, Palmer Ricketts goes to great lengths to explain the population and make-up of the United States in the early part of the 1800s (71-76). He does so to illustrate the state of civil engineering (not formally called as such) and to highlight the haphazard way in which construction of bridges, tunnels, and other technological objects had continued through the hard work of relatively untrained "mechanics . . . with little knowledge of the resistance of materials or of the principles of the design of engineering constructions as practiced to-day (sic)" (Ricketts 77). Regardless, the university was a place that saw itself as an institute where students learned by doing, and this thinking also applied to the courses not immediately scientific in nature. Although Rensselaer Polytechnic Institute was primarily designed for students interested in the engineering sciences, the curriculum in the mid-1800s still had vestiges of traditional liberal arts coursework.

[67] Not much is widely known about Quackenbos other than what can be gleaned from his New York Times obituary and what little exists of his biography in obscure places online. He was born in New York City on September 4, 1826 and died on July 24, 1881. With the exception of one year in the mid-1840s in North Carolina, he spent his entire life living and working in New York City. He graduated from Columbia in 1843, attempted law school, but found it wanting, and became the principal of a private school for almost twenty years. In 1863, Wesleyan University conferred an LL.D. degree. He was also the editor of *Literary American* during the years 1848-1850. ("George Payn Quackenbos").

Quackenbos was a dedicated and wildly successful publisher. He seems to have been something of a polymath as well, having published successfully in the late 1840s in a variety of venues. Quackenbos published various textbooks on history and philosophy as well as rhetorics, grammars, and mathematics textbooks ("George Payn Quackenbos"). He published poetry, translations, and short pieces on the bible and morality in journals such as *The Literary American*, *Anglo-American*, and *Golden Rule and Odd Fellow's Family Companion*. Over 40,000 copies of his *Elementary Composition* were in print during the mid-to-late 1800s, and *The New York Times* gushed in his obituary, "There are few English-speaking schools in the United States where the name Quackenbos is not familiar" ("George Payn Quackenbos"). In light of Quackenbos' wide-ranging and successful publishing career, *Advanced Course of Composition and Rhetoric*, then, can be read not only with Rowland's education in mind but as a widely-used text embodying the primary modes of writing and argumentation that many scientists were exposed to in their early university careers.

It does not appear that Quackenbos was interested in crafting new theories of rhetoric or new knowledge in any particular discipline; he seems to have had a knack for synthesizing the work of other writers rather than adding an original voice to the theoretical commitments of rhetoric, but the text included long discussions on "taste, the sublime, and prosody" (Lindsay 529). An explication of Quackenbos' *Advanced Course of Composition and Rhetoric* reveals a focus on the centrality of taste and imagination in the composing process. These two concepts are central to the nineteenth-century rhetorical training aimed at improving the natural ability of students, and taste was particularly foundational for a successful development and use of the imagination;

training a student's taste was a central part of refining the imagination. As Sharon Crowley argues, "teachers [could] offer instruction in how to strengthen natural endowments through discipline and exercise" ("Invention" 54). Quackenbos explains, "Hence it follows that Taste is eminently an improvable faculty; and in the case of this, as well as all mental and bodily powers, exercise is to be regarded as the great source of health and strength" (117). Both concepts where understood as intrinsic to the writer and improvable through instruction—taste, or the ability to judge, could be refined through practice, and imagination could be improved through exposure to new ways of representing thought. There were sanctioned responses to aesthetic experience and taste and imagination were the conduits for this experience.

Quackenbos' *Advanced Course in Composition and Rhetoric* was typical of the period and remarkable only for its total synthesis of Scottish New Rhetoric methodology and epistemology and its plethora of written exercises for students. In *The Evolution of College English: Literacy Studies from the Puritans to the Postmoderns*, Stephen P. Miller notes that Quackenbos' text offered overworked composition teachers an "extensive apparatus of exercises" (260). Kathleen Welsch notes that Quackenbos' rhetoric was expressly a practical guide to composition, and the students were often expected by the very format of the courses to engage in all of the teaching and learning activities (5). Its practicality was the result of a synthesis of the faculty psychology of Scottish Rhetoricians like Campbell and Blair with a desire to routinize the writing process for American students. The result was a mixture of the mechanical aspects of the Scottish New Rhetoric's faculty psychology with the elevation of taste to the status of a faculty.

Quackenbos' rather mechanical focus on taste was in line with its importance in nineteenth-century rhetoric. Nan Johnson argues that by the mid-nineteenth century taste and belletristic rhetoric had gained "theoretical primacy" *(Nineteenth-Century* 36*)*. Quackenbos draws heavily from Campbell and Blair, and his rhetoric reflects their focus on the belles lettres tradition; the text details the appropriate function of taste for the student writer. He begins Lesson XXXIV, "Taste: Its Universality and Cultivation," by explaining the relationship of rhetorical rules to taste. I cite at length to demonstrate how Quackenbos highlights the extreme importance of taste to rhetorical practice:

> The rules of Rhetoric and Criticism are not arbitrary, but have been deduced from examinations and comparisons of those great productions which in all ages have elicited the admiration of men. Striking passages have been analyzed; the peculiarities which render them pathetic, sublime, or beautiful, have been investigated; and thus rules have been formed, by which the critic is enabled to judge of other literary performances, and the writer is shown how to express his thoughts in such a way as to reproduce similar impression. (115-116)

He argues that taste is a faculty capable of perceiving the sublime and the beautiful, but it could only do so in conjunction with reason and imagination (116). Ultimately, Quackenbos believes that taste is an improvable faculty and one vital to critical activity. It could be taught, but at the same time each individual has an innate faculty of taste of greater and lesser quantities and strengths.

Quackenbos gives us a very classed version of taste – refined men own a more innate sense that is easier to refine, and he goes some way in explaining how taste is central to his understanding of a critical rhetorical practice (Quackenbos 120). In the text, the universality of taste is guaranteed through a common understanding of the type of person who possesses the faculty in its more refined state. This is an important point to understand because it supports an educational agenda clearly situated within a professionalizing middle-class. Quackenbos' argument normalizes the faculty of taste primarily through the idea of education and refinement (117). Although he recognizes that individuals are endowed with taste to different degrees, he stresses the importance of education in refining taste as a faculty. Of course, this makes sense in the context of the textbook he writes, but it also suggests that the process of a professionalizing education, as experienced by Rowland and his classmates, would support the refinement of their taste. Finally, Quackenbos advocates for a sense of taste that is refined through an Anglo-centric education. He dismisses the notion that each individual has his own standard of taste and argues that the universal standard to which one can be trained is culturally superior as well. The standard of taste is not enough to generate composition that would be considered tasteful. Taste, after all, is a critical faculty; it is a standard of judging expressed through the critical faculty. It is imagination that sparks the creative process.

Imagination constructs a sense of the natural world, and, as a faculty, each individual is endowed with different capabilities to recognize and express an aesthetic experience of an object. In particular, Quackenbos formulates the imagination as a conscious awareness—an analysis and synthesis of the natural world. Crowley explains that, while the Scottish New Rhetoric was an internal, mental process where "writers made connections between ideas," the paradox of the New Rhetoric's positioning of the writer was that its model for the composing process came from psychology, which "located the available materials for invention outside writers' minds" (*Methodical Memory* 62-63). Locating materials for writing outside of the writer's mind effectively shifted the burden of invention to the senses and perception. According to this theory, the writer takes input from the senses and reorders the natural world in a pleasurable way (Quackenbos 126). Quackenbos explains, "The difference in [aesthetic] effect is clearly not attributable to the objects themselves, nor to the external senses on which the impression primarily produced; it arises from a difference in the state of our imaginations" (Quackenbos 126). So, the aesthetic experience originates in the faculties of the individual and not in the object under scrutiny, and the imagination explicitly performs this activity.

Quackenbos' view of imagination's relationship with the senses replicates earlier explanations of imagination framed within rhetorical training. In particular, Francis Bacon, Karl Wallace explains, suggested a conceptualization of imagination whose "activity had its origin in the work of the five senses . . . yet they occurred in the absence of the sense images that gave rise to them" (66). Furthermore, once imagination had reconstituted the source material of the sensory world, reason could then interact with imagination, "joining" with it to create new ideas (Wallace 76). This understanding of Bacon's rhetorical imagination clearly informs the presentation of imagination in Quackenbos; the imagination synthesizes a new understanding of the physical world. This, in turn, demonstrates the fluid ways that imagination can bridge the exterior world of nature and the interior world of the rhetor in order to be expressed in a formulation by the individual.

For Quackenbos, without a properly aligned and trained sense of taste, the imagination would not have reliable sensory input to take apart, find patterns in, and recombine, and that lack would then preclude the subject from enjoying the object before him.[68] So, Quackenbos starts this section by focusing on the pleasure of imagination, which can only be obtained through a properly aligned critical faculty of taste. Imagination is a faculty of the mind "by which it conceives ideas of things communicated to it by the organs of sense, and, selecting parts of different conceptions, combines them into new wholes of its own creation" (Quackenbos 125). Imagination is the creative faculty by which the appropriate material, selected through the refined critical faculty of taste, is recombined into something. The pleasure that Quackenbos believes is found in the imagination derives from creative recombination of elements. It is an active pleasure that involves the individual, and it is based on the critically informed experience of the objects under review as well.

Rhetoric, then, demands that the student first learn to regulate his senses appropriately so as to be in the best possible state of mind to perform the critical operation that Quackenbos states is central to rhetorical practice—composition. In Quackenbos' text, taste and imagination are central to an understanding of rhetoric as a "useful art" that equips writers with a critical faculty for studying problems in other work. His textbook is designed to instruct students in how to be discerning readers and successful writers—the twinned faculties of taste and imagination are the mechanisms by which students can be discerning readers and writers. Quackenbos explains, "From this study of Rhetoric, two great advantages result: first, it enables us to discern faults and beauties in the compositions of others; and, secondly, it teaches us how to express and embellish our own thoughts, so as to produce the most forcible impression" (113). The

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[68] See Donald Salper's "Imaginative Component of Rhetoric" where he demonstrates how classic rhetoric views imagination and reason. He argues that imagination is synthetic and reason analytic (309).

reader is led to believe that the primary goal of rhetorical training is to support a critical art aimed at evaluating compositions, rhetors, and audiences.

Rhetorical theories were directed towards an understanding of the rhetor as well as how to most effectively craft an argument. Rhetorical training inculcates students with values that make them more critical readers and more productive writers. Students' analytical skills are sharpened, and these skills are directly linked to the composing process. Furthermore, as Johnson explains, the critical faculty of taste allows students to have access to aspects of "human nature" normally outside of "science proper" (*Nineteenth-Century* 35). The interest in the mental faculties allowed rhetoric to become a tool by which to study human nature. Although rhetorical theory relied on epistemological assumptions to focus its study, it also offered the rhetor with tools to critique and augment his or her practice.

Rhetoric could teach student rhetors to perceive and process the natural world in order to improve useful composition strategies. In *Methodical Memory,* Crowley explains that proponents of this method "offered their students goodly amounts of advice" (63). However, in a separate piece she contests this seemingly egalitarian view of Quackenbos. In "Biting the Hand That Feeds Us: Nineteenth-Century Uses of a Pedagogy of Taste," Crowley argues that taste was taught as something both innate to the student and learnable through study. She reconciles this paradox by examining how taste was used to include and exclude parties to a classed based system of learning.[69] This more subtle view of taste's teaching and function is informed by Crowley's uncertainty

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[69] For a discussion on Quackenbos' rhetoric excluded individuals based on gender, see Nan Johnson's "Parlor Rhetoric and the Performance of Gender in Postbellum America" in *Rhetorical Education in America* pages 111-112.

over why nineteenth-century rhetoric instructors were interested in teaching a concept that was more common in philosophical conversations (Crowley, "Biting" 12). And while Crowley is interested in arguing that the object of teaching taste is to form a community of writers that could identify members and nonmembers, it is figured as a teachable faculty, and that the mechanism through which it can be taught is the work of writing – i.e. the labor of following a system of composing rules.

Nineteenth-century rhetoric, then, is an informative way to understand the formulation of the study of the imagination during this period. For Quackenbos, it is a critical faculty that helps the individual process and express experiences of sensory data. Formal rhetorical study elucidates these connections for the student, but it also codifies an understanding of how these faculties work together to create new arguments acceptable to a particular community's standards. It is this codification, circulated throughout the culture, that can be helpful in understanding Rowland's discussion about imagination in scientific activity. As in Quackenbos' formulation, imagination is a mental attribute of the scientist that is central to working within the field; it allows the individual to recombine knowledge of the world to make new statements. Quackenbos presented imagination as a central part of making sense of the world, and he offered students a critical framework for discussing it.

Rowland's Conception of the Scientific Imagination

For Rowland, scientific imagination judged prior work, addressed problems, produced scientific practice, and was legible to a community of practitioners. But, it is also a force that must be constantly guarded against because it can overrun the reason and the necessarily more mundane aspects of scientific practice. Above all, scientific imagination, as constructed by Rowland, suggests a scientific ethos grounded in the ability to start research in the proper place and in response to the properly identified exigence; the ability to do so comes from the scientist's imagination. So, scientific imagination becomes a primary element of scientific ethos, and in Rowland's speeches, his discussion is aided by rhetoric's framework for understanding the function of imagination. In his many public speeches in support of physics, he returns again and again to scientific imagination as a productive and necessary tool for engaging with the natural world. Part of this argument articulates his goals for the profession, and part of this argument is bound up with the complexities of funding a resource intensive profession. As funding became an ever-increasing concern for research science, scientific ethos and its major component part—scientific imagination—became increasingly important to define. Scientific imagination was a legible way to describe the interior process of scientific work.

In the nineteenth century, the imagination is central for articulating an aesthetic response to scientific practice and for formulating an aesthetically pleasing scientific argument; training students to be open to this response was important to Rowland's larger construction of scientific ethos. Robert Kargon explains that Henry Rowland was intensely interested in the mental and moral training of graduate students (131). Furthermore, the laboratory was the critical site of this training, and its outfitting and funding were a constant struggle for Rowland. The connection between an aesthetics of science and the imagination informs Rowland's construction of an imaginative scientific ethos; a rhetor's own conceptualization to an approach to scientific practice diffuses a sense of the aesthetic in response to many different exigencies—from laboratory practice, to garnering support for funding, to training of future generations of scientists. In his advocacy for a refined training of science students, Rowland articulates the clearest construction of scientific imagination and its relationship with scientific ethos.

The three most important addresses that deal with the scientific ethos of imagination are "A Plea for Pure Science" (1883), "The Physical Laboratory in Modern Education" (1886), and "The Highest Aim of the Physicist" (1899). In each of these three speeches, he develops his thesis that the work of the physicist is uniquely valuable because it involves imaginative processes. Furthermore, Rowland argues that scientific practice demands a special financial commitment from the country to its universities to develop these abilities. Each speech focuses on different relationships of scientific practice and imagination to the world. In "A Plea for Pure Science," Rowland focuses on the importance of pure science to technological developments in the United States. By doing so, he outlines the multiple audiences that the scientific rhetor must address. In "The Physical Laboratory in Modern Education," he argues that the physics laboratory fundamentally challenges the student's mind to experience truth and error. It is central to an educational regime that seeks to train thinkers. In his final speech "The Highest Aim of the Physicist," Rowland directs his argument towards other physicists to articulate a vision of the true nature of their scientific practice. In each of these speeches, he builds upon a scientific imagination central to scientific practice in the demanding field of physics. Each speech describes an iteration of scientific imagination, which is part of an ethos of scientific practice.

The moral and mental discipline Rowland advocated mainly focused on what he felt were the two primary functions of physicists—to evaluate data and experimental results for accuracy and to create new theories, which explained these facts and data.[70] Both activities are central to creating a scientific ethos. Aesthetic criteria were embedded within these two activities, which exist as expressions of scientific practice but also operate as submerged imperatives that express extra-empirical values, which, in turn, are central to representing empirical practice to professional and lay audiences. In short, Rowland's ideal physicist was a critical and imaginative practitioner whose focus was turned inwards towards his field but re-presented to an external world, which did not necessarily understand his practice in terms of a market-driven economy. The importance of uncovering the connections between the two activities of physicists and the larger context of their work can be found in the way their arguments illuminate the power in a rhetorical approach to an understanding of an aesthetics of science. The same critical faculty that can make aesthetic judgments must first be able to make field specific judgments and then create new knowledge.

"A Plea For Pure Science" – The Scientist as Artist

"A Plea for Pure Science" is the most well known of Rowland's public speeches supporting physics research in the United States, and it exemplifies the stakes of generating the appropriate scientific ethos for practitioners in the emerging field. As the Vice-President of Section B of the American Association for the Advancement of

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[70] See George Sweetnam's *The Command of Light*. Although physicists were excited that Rowland's devices were so accurate, they often lamented the sheer amount of data the same devices produced (Sweetnam, *Light* 54).

Science, Rowland delivered this address on August 15, 1883. In it, he simultaneously celebrates advancements in physics in the United States and exhorts his colleagues to become even more vocal supporters of funding for the discipline. In particular, Rowland articulates three important items: the relationship between commercial science and research science; the relationship between research science performed within the university as opposed to regional amateur scientific societies; and the role and duties of the individual scientist within these larger institutional and financial relationships. In this last item, he underscores the importance of the individual's work for advancing the goals of the institution; this point is particularly important for understanding the tenuous position of the research physicist in the nineteenth century. Underneath these descriptions and exhortations runs a concept of how the imagination plays a role in defining the role of the individual researchers in each. Above all, Rowland argues for a professional, well-financed cadre of research physicists located in the university, and this argument implicitly recognizes the multiple audiences of the scientific rhetor. His model highlights the need for a scientific ethos that is both morally strong and technically well versed.

The central thrust of this argument for more and better funding for the sciences can be understood in how he sees adequate funding as central to scientific understanding:

> It is very often said, that a man has a right to his opinion. This might be true for a man on a desert island, whose error would influence only himself; but when he opens his lips to instruct others, or even when he signifies his opinions by his daily life, then he is directly responsible for all his errors of judgment or fact. He has no right to think a molehill as big as a mountain, nor to teach it, any more than he has to think the world is flat, and teach that is so. The facts and laws of our science have *not* equal importance, neither the men who cultivate the science achieved equal results. (Rowland, "Pure Science" 609-610)

In short, he argues that a community of practitioners is responsible for propagating and teaching the appropriate information. In other sections of his speech, Rowland clearly explains that this responsibility is intrinsically tied to appropriate levels of funding, so that a national community of physicists located in universities can adequately accomplish this task. Once a community of scholars and students are introduced to the lone researcher, he then has a duty to make sure that his work is accurate. The presence of a real and imagined community places pressure on the scientist to perform accuracy in a legible fashion, but that accuracy must also result in knowledge that is useful to the community.

In this speech in particular, Rowland has a clear dislike for regional scientific societies, which operate outside the auspices of university science. He believes that they do not offer the proper training and reflective qualities of the university for an accurate study of the natural world. Specifically, Rowland objects to the lack of trained professors in these smaller educational institutions ("Pure Science" 601-603).[71] Furthermore, the proper researcher is responsible for all of the facts of his research and must not let his imagination overtake his other faculties; he cannot make "mountains out of molehills." Rowland sees the value of the researcher's work only within a community of scholars and teachers. Responsibility extends outwards to the community through the research. This

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[71] See Edward Shils' "The Order of Learning in the United States: The Ascendancy of the University" in *The Organization of Knowledge in Modern America, 1860-1920*. Shils' thesis is that the university rose in stature because it was better able to organize capital and equipment for the purpose of knowledge production and dissemination.

responsibility exists in relationship to the wider world as a teacher and a researcher that can be undercut by minor institutions that do not employ rigorous scholars.

The responsibility of the research scientist in the nineteenth century was used to support a moral understanding of scientific practice and vice versa. In *The Scientific Life*, Steven Shapin outlines the relationship between theoretical scientists and commercial scientists and the ways in which scientific activity was based a sense that scientists were morally superior to other people (24). Specifically, he argues that, since Darwin, nature was reconceived as an object of secular study rather than sacred study, and the scientist was the observer who had the moral authority to engage in such relationships (Shapin 25). Shapin, then, sketches out an image of the scientist as someone who had to adapt himself to the new roles of the "knowledge-producer," who would serve the nation-state rather than "humanity," and American scientists in the late 1800s found themselves in the position of having to justify their position in national politics and support the pursuit of science in the academies of the time (56-60). For Rowland, this negotiation took the form of explicit recognition of the expertise of the scientist. The scientist as expert was a position that Rowland vigorously supported, even to the point of zealotry. However, at the root of his argument for "pure science" was a desire to maintain just the type of conception of the scientist as Shapin describes. According to Rowland, the "pure scientist" is of a nobler breed than the common man. In large part, the nobility comes from the scientific imagination—the ability to creatively approach a research problem and generate new knowledge.

It was this view of "pure science" that informed Rowland's discussion of scientists and their value within a research agenda. To further his claim that "pure" science is of a higher order of work than technological engineering and should be funded as such, he links the theoretical scientist with the artist:

> The successful sculptor or painter naturally attains to wealth through the legitimate work of his profession. The novelist, the poet, the musician, all have wealth before them as the end of a successful career. But the scientist and the mathematician have no such incentive to work: they must earn their living by other pursuits, usually teaching, and only devote their surplus time to the true pursuit of their science. (Rowland, “Pure Science” 598)

The quote above harkens back to Rowland’s earlier statements about the lack of financial gain associated with scientific labor, but it also creates a link between the artist and the “pure” scientist. The stress on the “legitimate work” of the artist and the correlation to the “true pursuit” of science suggests a connection between the rhetorical work of scientific argumentation and the national project to fund science. The true scientist, like the artist, is engaged in the legitimate work of creating—of formulating systems that put facts into relationships with one another. Rowland further argues that the nation needs these scientists, whose time is spent on their true pursuit. He frames the necessity to properly fund scientific research as cultural competition with Europe that has repercussions for future economic resources. This competition for limited resources contextualized the responsibility of the scientist within a larger community of researchers. Now, the research scientist must also be aware of the community and nation outside of the laboratory.

Rowland ends this address with a reminder to the audience of the stakes of their enterprise:

> The problem of the universe is yet unsolved, and the mystery involved in one single atom yet eludes us. The field of research opens wider and wider as we advance, and our minds are lost in wonder and astonishment

> at the grandeur and beauty unfolded before us. Shall we help in this grand work, or not? Shall our country do its share, or shall it live in the almshouse of the world? ("Pure Science" 613)

Even here at the end of the address as Rowland urges his listeners to agitate for funding and support for their work, he sees the researcher as almost overwhelmed with the sensory data of nature. The grandeur of the universe overpowers them and their minds become "lost." However, in light of his earlier statements of in support of critical approaches to the natural world and the responsibility the researcher has to his community of professionals, there is little doubt that Rowland believes that properly outfitted and supported university researchers will be able to address these wonders. But, it will be their training that best prepares them to meet the challenges of the universe and not lose themselves. Armed with a critical practice of imagination, university researchers will be able to make sense of a sublime universe. For Rowland, the well-appointed physics laboratory as a site of education will be invaluable to this training.

"The Physical Laboratory in Modern Education" – Imagination in Practice

The importance of laboratory education and the necessary training of the scientific imagination are central concepts in Rowland's "The Physical Laboratory in Modern Education." Delivered on February 22, 1886 as the Commemoration Address at Johns Hopkins University, Rowland extends his earlier contention that scientific imagination is central to understanding the universe; he complicates this idea by including the concepts of error and accuracy as a way to understand the stakes of training young physicists. In this formulation, Rowland is much more concerned with yoking the training of the young scientific mind to reason and imagination to produce new knowledge. The scientific mind must be trained to identify error and seek truth, and it must also be able to know things through reason and create new knowledge through imagination. The ethos Rowland articulates in this speech is one that displays humility before nature but does not cease in finding errors in one's own work as well as the work of others.

The guiding principle in educating young minds is to train them to identify error. Rowland clearly positions this ability to find error within the corrective confines of disciplinary practice and appropriate deference to the theories and ideas of those who have come before. He begins his speech by laying out two extremes of thinking: on the one side is the individual who accepts everything unquestioningly from his peers and on the other side is the individual who ignores the work that has come before and seeks to create new knowledge out of whole cloth. As Rowland explains, the preferred position is in between these two: "Intermediate between these extremes comes the man with full respect for the opinions of those around him, yet with such discrimination that he sees a chance of error in all and most of all himself" ("Physical Laboratory" 614). The ability to discern error in one's self and in others comes from a technical training in the scientific laboratory based on a morality aimed at rooting out error. In other words, Rowland sees the scientist's authorization to root out error in other's work located, in part, in the ability to discern error in one's own work. In formulating scientific ethos in this fashion, Rowland links technical prowess with the individual's moral aptitude, suggesting that scientific ethos is created not just through proper demonstration of technical ability but also through the proper demonstration of an internal moral sense as well. In fact, scientific ethos is predicated upon a proper understanding of the individual's technical prowess as motivated by his moral sensibilities.

Rowland argues the student must be exposed relentlessly to his errors of thinking, and by doing so, will train his reason and know humility before nature and its facts. This crucial step requires the student to recognize "nature has laws which must be discovered by labor and toil and not by wild flights of the imagination and scintillations of so-called genius" (Rowland, "Physical Laboratory" 616). It would appear that here Rowland believes repeated exposure to the unrelenting facts of nature will purge the would-be scientific mind of imagination. This is true in so far as Rowland sees it as part of an unregulated mental practice, which substitutes imagination for real facts, but when taste is introduced as a critical component for understanding scientific practice, then imagination regains its centrality to the project.

In an effort to link the function of error in training the scientific mind, Rowland uses language that echoes Quackenbos' description of taste's unequal distribution among individuals:

> Some are born blind to the beauties of the world around them, some have their tastes better developed in other directions, and some have minds incapable of ever understanding the simplest natural phenomenon; but there is a larger class of students who have at least ordinary powers and ordinary tastes for scientific pursuits. ("Physical Laboratory" 616-617)

In this example rhetorical theories of taste influence the formulation of taste's function and distribution in scientific inquiry. There is a similar attitude towards its influence that informs both fields of study. In this case, taste becomes the link between an understanding of where imagination fits into a scientific ethos, which seems primarily concerned with the creating the authority to discern faults and errors in theories and experimental data. Imagination in science reorganizes sensory data to create new concepts. It is an active practice that mimics the same action of the imagination in the Scottish New Rhetoric.

Towards the end of the speech, Rowland identifies the failure of modern education to instill an action-oriented mentality in students: "[T]he memory alone is trained and the reason and judgment are used merely to refer matters to some authority who is considered final, and worse than all, they are not trained to apply knowledge constantly" ("Physical Laboratory" 617). Ultimately, the action-oriented student scholars that Rowland hopes to produce in his educational laboratory are informed by a critical faculty, which supports the rhetor's ability to be a final arbiter on matters of error and accuracy. Although the individual scientist must be mindful of theories and concepts that have come from others, he must also be able to recognize when that knowledge is erroneous and move the larger project of scientific knowledge making forward.

Rowland grounds this perception in the ways in which the individual student's responses to the natural world are informed through repeated instruction; he ultimately connects this practice to imagination: "This, then, is the use of the laboratory in general education, to train the mind in right modes of thought by constantly bringing it in contact with absolute truth and give it a pleasant and profitable method of exercise which will call all its powers of reason and imagination into play" (Rowland, "Physical Laboratory" 617). Whereas the unfettered imagination obstructed scientific thought, once a critical understanding of the natural world is introduced, imagination becomes a faculty on par with reason—it works in tandem with it to formulate responses to the world. Although only re-introduced at the end of this speech, imagination serves to connect the analytical practice resultant from repeated exposure of theories to natural facts and a synthetic practice whereby students move beyond recitation of facts to a practice that acts in the world.

Rowland seeks balance between an overly analytical and overly synthetic scientific practice through the imagination. Both are a response to the wealth of data that "pure science" produces. Presenting these responses to an informed audience presents the scientific rhetor with a variety of obstacles to overcome in the process of writing an article. The content they have to write about comes mainly in the form of their data, but how they choose to approach that data is purely rhetorical and the purview of rhetorical practice. The appropriate stance towards this material is of the utmost importance for scientific practitioners in Rowland's view. The imagination is crucial for composing because it brings together many parts; it synthesizes many elements. The same can be said for Rowland's stance on the role of imagination in scientific practice. It is a critical component for a useful research practice—it assists the student in responding to exigencies in the laboratory and eventually in presenting findings to an audience.

"The Highest Aim of the Physicist" – Imagination as Goal

"The Highest Aim of the Physicist" was the final speech of Rowland's career and delivered as an Address as the President of The American Physical Society at the society's meeting in New York on October 28, 1899. In this speech, Rowland articulates the most fully formed description of scientific ethos for physicists, basing it in large part on the imagination. He returns to many of the same topics from his earlier public addresses—he gives a brief history of the field and repeats his lament that the pure sciences are not funded to the same extent as the technical aspects of the field. This speech brings together the prior themes of his two early addresses—the importance of community in scientific practice and the centrality of imagination as a faculty of the mind. Their combination is a culmination of Rowland's own philosophical outlook on scientific practice underscoring the tight relationship between the two supposedly separate fields.

For Quackenbos' brand of rhetorical criticism, proper production of a text required an appropriate stance towards earlier textual knowledge produced in the field; the purpose of rhetoric for Quackenbos was the analysis of texts with an eye towards improving the work of the rhetor. The imagination functioned for Quackenbos and Rowland as the faculty that would best process prior knowledge, recombining it with new data to produce work. Rowland actually extends the usefulness of this critical understanding of imagination by situating it within the complex relationships between the professional scientists and the general public responsible for funding the activity. In fact, he suggests that imagination is the faculty best adapted for advancing scientific thinking. Through imagination's power to analyze prior knowledge and recombine it, the scientist can address the limitations of current practice and devices. Like Quackenbos, Rowland presents imagination as a way to respond to an object under scrutiny in a productive manner. Ultimately, Rowland describes an ethos of scientific activity grounded in the imagination, and he codifies this ethos so that it can be legible to the community of physicists who will judge the appropriateness of a scientist's imaginative intervention in research or argument.

In this speech, Rowland reminds the listeners about the historical and present community of scientists, but he does so to remind his audience about the appropriate way to conceive of themselves as practitioners and composers in the field. Rowland explains that they are an "aristocracy" of learned individuals and that the societal meetings are for "mutual sympathy and the interchange of knowledge" ("Highest Aim" 668). Rowland, never shy about his desire to elevate the physicist above others, describes a community of scholars that excludes the layperson who does not understand or devote himself to the field, and he is quick to implore his listeners to consider such an audience for their work. The labor of research scientists is useless if it is not circulated to a larger world (Rowland, "Highest Aim" 670). Presentation of research is as important as the research itself—circulation of ideas within multiple communities is vital for the continuation of the field.

Rowland hints at the limited use of experimental devices in trying to tease out the problems of physics. In a section that would seem to undercut his own work in crafting precision instruments, he argues that they do not offer enough proof for making statements about larger, more complex problems. For instance, Rowland references the law of gravitational attractions, and explains that a few measurements in a laboratory do not offer the kind of proof necessary to make statements about physical laws because the scale of the experiments does not match the scale of reality ("Highest Aim" 671). Throughout this section he urges his listeners to continue studying these problems, but he suggests that the limits of then current laboratory technology will prevent researchers from gathering the necessary data to substantiate their theories. It is at this point that Rowland turns towards imagination and the echoes of the faculty psychology to make his case for an appropriate and useful stance towards scientific practice and scientific thinking.

The theoretical scientist, according to Rowland, must have a flexible mind, and this flexibility is to be found in the imagination. Like Quackenbos' synthesis of the Scottish New Rhetoric's approach to the mind, Rowland's argues that imagination's centrality to scientific practice must be balanced with reason ("Highest Aims" 674). This balance is necessary so that the scientific investigator does not allow his imagination to overtake the data available through research. In short, Rowland is quick to warn against making the facts fit the theory, but he stresses the importance of imagination in initially sparking the investigation. This is the clearest formulation of the action-oriented activity Rowland previously described in "The Physics Laboratory in Modern Education." The faculty can be developed in the individual, but it must be managed so as to avoid counterproductive research and theorizing.

Rowland warns that extrapolation is the most common trap for young physicists. If they use an equation or theory beyond the initially intended limits, and the process "becomes one of pure imagination specially liable to error" ("Highest Aims" 675). Pure imagination brings about a violation of scientific practice leading to Rowland's central interest, error. Like rhetoric, scientific investigation requires an appropriate attitude towards balancing the mental faculties that, if not properly managed, leads to unsuccessful presentations of knowledge produced in the laboratory. This leads to a clear reckoning with the provisional shape of scientific knowledge:

> All the facts which we have considered, the liability to error in whatever direction we go, the infirmity of our minds in their reasoning power, the fallibility of witnesses and experiments, lead the scientist to be specially

> skeptical with reference to any statement made to him . . . How shall we regulate our minds with respect to it: there is only one way that I know of . . . The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error. (Rowland, "Highest Aim" 676)

The highest aim for the research scientist is to maintain this balanced state of mind—one where the imagination can help spark the necessary investigations and one that does not take liberties and generate erroneous work. Neither the moral scientist nor the technical scientist can achieve such a feat. Only through the moral and technical ability as enacted through the imaginative scientist can this balance be achieved. Furthermore, the value of this achievement is relative to the community in which the scientist works. The work of others is being judged and those evaluations are being represented in the world for further discussion through scientific writing.

In this final speech, Rowland articulates a way for physicists to construct an ethos based on imaginative responses to error. If accurate judgment grounds aesthetic judgment, then there must be a conceptual mechanism in place to respond to error. However, it is crucial that this response is productive—imagination's ability to process the natural world is central to producing useful responses to research problems and prior questions. In order to be productive, the scientist's imagination must be used to approach these problems in new ways, but it cannot override other fundamental aspects of scientific work. Above all, scientific judgment must be legible to the larger community of practitioners—it is the only way that scientific ethos can be properly displayed to an audience.

An Ethos of Imagination: Responding to Error in a Community of Scientists

In each of these speeches, Rowland articulates and celebrates an ethos for physicists. In his speeches, we see how he carries forward an argument that seeks to make real cultural, economic, and political change. He wants to elevate the thinking about imagination's role in scientific practice so that there can be substantial structural changes in how scientific research is funded and carried out. In doing so, he weds a stance that is rhetorical with one that speaks to an immediate need for increased appropriations for "pure" scientific research.[72] His formulation directly relies upon a sense of a community minded, flexible, and productive scientific labor and presentation. These speeches represent a career-long understanding and promotion of scientific ethos founded in an imaginative practice. Moreover, Rowland understood this ethos to be useful for making arguments that represented a scientific practice, which used accuracy and error as fundamental topoi for further discussions.

The flexibility of Rowland's scientific ethos is its ability to represent the identification of appropriate material for critique and evaluation of that material in a fashion that best moves communal knowledge forward. Rowland's discussion of the scientific imagination serves to codify its place in a conception of scientific practice. For Rowland, managing the imagination and its products are central to constructing scientific ethos. The managed imagination can open the laboratory practitioner to new ideas and directions of study. Rowland's continual discussion underscores the foundational ways in

[72] See Cynthia Sheard's "The Public Value of Epideictic Rhetoric." She explains that the function of the epideictic is to bridge the rhetorical and the philosophical. Sheard argues, the function of epideictic is timely and kairotic (768). It may appear that Rowland's insistent celebration of scientific imagination is a universal celebration, but it is in fact one that responds to the economic, political, and informational needs of the day.

which these practices are similar and how borrowing from rhetorical training can inform not only presentation of material but also the philosophical approach to the practice of one's art. For one, Rowland wishes to create a regimen for a creative way to deal with the increasingly dense pile of factual data produced by "pure" researchers. In an environment that grew increasingly fecund with facts, the scientist was buried beneath them, but he had to make theoretical headway or else risk the possibility of not pursuing a research agenda. The attitude Rowland advocates is flexibility rooted in an imagination; this flexibility is wholly geared towards effectively addressing error in scientific practice and argument.

Error occupies a unique space within a scientific practice creating useful knowledge that is factually correct and reliably accurate. Publicly engaging error (i.e. recognizing error and speaking/writing to it) becomes a prominent part of scientific practice in the nineteenth century, but, as Lorraine Daston explains in "Scientific Error and the Ethos of Belief," it is a practice that is not wholly divorced from earlier concerns about error in scientific practice (1). Daston sees the shifting ground of what constitutes appropriate knowledge as having possible generative value in the sciences. The tension between error and accuracy make up this ground, and it informs the scientific rhetor as well. Their ethos is created, according to Rowland, in large part through a continual internal engagement with the error of their theories and the work towards accurate knowledge claims. When addressing error, ethos and topoi become ever more tightly bound together in the act of scientific argumentation.

Like Rowland's admonition to be wary of "wild flights of imagination" that lead to unproductive extrapolation, Daston's argument explains that identifying error is central to constructing a sense of scientific self. She argues:

> [T]he analysis of error is integral to demarcating genuine knowledge from mere belief and, among beliefs, the justified from the unjustified. Vigilance on this score is conceived to be moral as well as intellectual: the will as well as the reason must be mobilized in order to grant assent only to those claims that, after thorough epistemological vetting, deserve to be credited. (Daston, "Scientific Error" 6)

It is only through the proper control of the imagination, the moral duty of the scientist, that error and accuracy are balanced in a fruitful dialectic relationship. The tension between error and accuracy is only resolved (or addressed) through the application of reason to the imagination.

Daston explains that in the nineteenth century "The healthy imagination was regarded as essential to an integrated self, for it was the faculty responsible for fusing sensations from the various sense organs into a unified sense impression" ("Scientific Error" 15). The moral standing that scientists have comes from controlling and maintaining a "healthy imagination" that will craft a gestalt of experience from a variety of input from the different senses. It is the regulation of this gestalt process that generates anxiety within scientists. This is what Daston calls "Projection;" the input material from the senses is manipulated by an uncontrolled imagination resulting in a theory or result that is in error:

> The will was one faculty among several in Enlightenment theories of the impressionable self, and of minor cognitive consequence: it was charged with controlling the passions, but not sensation and imagination, which were properly subordinated to reason and judgment. In contrast, the will dominated all aspects of the subjective self, including those related to the acquisition and evaluation of knowledge. ("Scientific Error" 18)

In science, error springs from the senses and the imagination. It is a problem that is largely internal to the scientist and therefore the solution must come from the scientist himself, but in some way must be exorcised in public to demonstrate the scientist's commitment to that project. Whereas Daston sees these discussions as prophylactic in nature ("Scientific Error" 6), I see them as much more performative and, ultimately, generative for scientific practice and an aesthetics of science. A managed imagination is part of the ethos of scientific practice. Demonstrating this managed faculty is central to the task of creating an ethos of accuracy legible to an audience.

As Rowland has outlined in his speeches, error and truth (or accuracy) are not quite the antithesis of each other. Instead, they exist on a continuum that must be constantly revisited and revised. Error is an artifact of practice or a state of being, while accuracy is a descriptor of practice. Scientists do not usually speak of erroneous practice so much as the results of that practice, while they strive to maintain accuracy in their practice. As an evaluative topos, error is used to structure the text, and the rhetor's response to the topos informs the construction of scientific ethos in the text. In his speeches, Rowland outlines an ethos of scientific practice that is directly constructed on the use of the topoi of accuracy and error in scientific writing. Although he presents these as functions of scientific practice, these topoi must be made legible to audiences, and through this presentation they help construct a scientific ethos that Rowland argued was the central to the burgeoning field of physics and its growing cadre of researchers.

Evaluative Topoi and Ethos in Scientific Writing

Evaluative claims are central to the discussion of an aesthetics of science, and they are also central to the production of knowledge within scientific practice as well. In particular, evaluative topoi are the rhetorical meeting place of the two poles described by Patton and the dialectical contest elucidated by Gross. Evaluative topoi such as error, accuracy, elegance, simplicity etc. are the result of an encounter between the rhetor and the world and they are the moment when the scientific rhetor makes use of authoritative values of his or her field to suggest an innovation within the field. The successful use of evaluative topoi relies on the scientific rhetor's ethos, which is constructed rhetorically and defines the boundaries of the topoi in the text.[73] Locating topoi supports the extension of knowledge by creating a context for what will be discussed. A rhetor creates a scientific ethos through the use of evaluative topoi, and the uses of those topoi are supported by the appropriate scientific ethos. The reinforcement necessarily obscures the connections between the two elements of rhetorical scientific situations. In part, this obscurity makes it easy for scientific rhetors to lay claim to an ethos that can fulfill

[73] See Lawrence Prelli's "The Rhetorical Construction of Scientific Ethos." *Landmark Essays on Rhetoric of Science: Case Studies*. Scientific ethos, as Prelli explains, is constructed rhetorically ("Scientific Ethos" 88). By this, Prelli means that the audience does not give ethos; rather, the rhetor must create it through his or her discourse, and ethos is created because "[r]hetors respond to, or seek to avoid creating, ambiguities and conflicts about their scientific credibility" ("Scientific Ethos" 88). The centrality of scientific credibility to evaluative topoi is found in the ways in which scientific ethos describes the boundaries of topoi. Citing Robert K. Merton's work, Prelli notes "scientific *ethos* binds both technically and morally" ("Scientific Ethos" 87). In the case of scientific argumentation, ethos is both a moral force because it asserts what is right, and it is a technical force because it explains to rhetors the "efficient procedures for securing the extension of knowledge" (Prelli, "Scientific Ethos" 87).

requirements for extending knowledge and make extra-empirical value claims. The successful use of evaluative topoi also cements the scientific rhetor's ethos.[74]

The connection between scientific ethos and evaluative topoi is particularly useful for determining in what ways scientists approach questions of aesthetics in their practice and in determining the worth of their individual project in relationship to other scientists in their field and to other institutions in the world. Rowland constructed a scientific ethos based on imaginative thinking that could successfully establish evaluative topoi as central to particular lines of argument.[75] This ethos was central to his successful use of the evaluative topoi or error and accuracy. He lectured his listeners to establish an ethos appropriate for a rhetorical situation that called for both humility before nature *and* a faculty critical enough to discern errors. Scientists are able to enact an aesthetic judgment of scientific work through the connection between ethos and evaluative topoi.[76]

Evaluative topoi define the areas that scientific rhetors can identify as appropriate for beginning discourse. The community of scholars engaged in the discourse in turn, defines topoi appropriateness. In particular, the evaluative topoi of accuracy and error exist within a continuum of values within a community of scientific practitioners, and the importance of these terms as evaluative concepts rests within a shared understanding of

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[74] For an examination of the intertwined nature of the elements of a rhetorical situation, see Keith Grant-Davie's "Rhetorical Situations and Its Constituents."

[75] For a similar argument about how figures suggest a line of argument see Jeanne Fahnestock's *Rhetorical Figures in Science* pgs. 23-24.

[76] For a lengthy discussion on how scientists make aesthetic judgments by projecting values into theories, see James McAllister's *Beauty and Revolution in Science* Chapter 2: "Abstract Entities and Aesthetic Evaluations." In this chapter, McAllister argues that in order to determine a theory's aesthetic value it is important to understand the effect of "properties of that theory on scientists or observers" (*Beauty* 31).

the ethos of the scientist. This construction process is central to deploying evaluative topoi effectively to command assent in a scientific argument. This is especially true for evaluative topoi that speak to idiosyncratic results arising from instrumentation, but it must also be true for the evaluation of an argument as well. The topoi of error and accuracy are deployed to support arguments for what constitutes good work and to argue for increased funding for the practice of this good work. In this way, topoi, and the critical faculties are tied together in a nineteenth-century schema of rhetorical practice, which highlights an aesthetic of error and accuracy in scientific practice and argument. In particular, Rowland used error and accuracy as evaluative topoi in his work, but by understanding the imaginative aspect of his formulation of scientific ethos, we can understand how these two areas, often thought of as overly determined by matters of fact, are surprisingly rich areas for aesthetic interventions. For Rowland, the imaginative scientist is one who can address error in a creative fashion but within the constraints of his or her field. Rhetorical imagination is a critical element to an aesthetic awareness that allows for flexibility in approaching an exigent problem. Error and accuracy are evaluative topoi which Rowland uses to great effect in his scientific writing, but they should be understood within the framework he lays out in his public speeches for the imaginative scientist who must utilize judgment in order to be productive and to enact an appropriate scientific ethos.

Evaluative topoi are necessarily comparative, and this comparative aspect requires an imaginative and flexible approach to argumentation. Although Lawrence Prelli explains that evaluative topoi like error and accuracy suggest values that are "inherent to empiricism" and are "values empirically cogent work must have," he does not mean to say that these values are absolute. He argues that two proponents of a theory likely argue over the comparative accuracy of data, and that accuracy is such a central topos in scientific argument that its use is "almost automatic" (Prelli, *A Rhetoric of Science* 199-200). However, as has been demonstrated through Rowland's public addresses, the scientific ethos needed in order to use the topos of accuracy is not automatic. In fact, it has been exhaustively discussed and constructed through education and argument.

Therefore, the topos of accuracy references the community-held value of tightness of fit between facts, theories and nature.[77] In fact, when Rowland uses error and accuracy as evaluative topoi, he is concerned with how the mental faculty of imagination is encountering the world. A rhetorical analysis of his writings demonstrates that the faculty of imagination underlies his approach to accuracy in his project, and he sees this as the inherent value that "pure" research brings to the world. Much of Rowland's career focused on the uses of his instrumentation, and his professional interests lay in determining precise measurements of physical phenomena.[78] In particular, Rowland's history points to a lifelong interest in experimental devices and precise measurement. His interest in precision demonstrates his commitment to a scientific ethos that authorized much of his work in physics.

Accuracy in scientific practice is central to producing trustworthy data and new theories, so finding and addressing error is fundamentally important. However, error can

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[77] For the relationship between the facts of nature and scientific theories, see Charles Bazerman's *Shaping Written Knowledge*. In particular, Bazerman argues that science is comprised of "accounts of nature" (*Shaping* 60).

[78] See George Sweetnam's *The Command of Light* for an exhaustive exploration of Rowland's career measuring the visible-light spectrum.

only be exposed and accuracy evaluated when the scientist approaches it in a useful fashion. In "Is the Identification of Experimental Error Contextually Dependent? The Case of Kaufmann's Experiment and its Varied Reception," Giora Hon argues that erroneous statements can only be erroneous when they are "embedded within a set of statements which claim to constitute knowledge" (171). If these "claims to knowledge" do not cohere with the current theories and empirical statements, then they are erroneous. Furthermore, Hon claims that in order to "apprehend an error one needs a vantage point from which a statement that was thought to accord with the state of affairs is in fact found not to cohere" ("Contextually Dependent" 171). In other words, coherence with previous knowledge claims is paramount to avoiding error, but only a scientific ethos positioned to address incoherence and error can address this situation.

Hon argues that the discussion of error in an experiment is one that is situated within the individual's philosophical and methodological disposition ("Contextually Dependent" 171). The philosophical and methodological disposition does not necessarily have to originate within scientific practice and philosophy. In Rowland's case, the disposition towards composing an argument is informed by rhetorical training rather than scientific work. The detection of error and the discussion of error are two different acts crucial to the work of science. Rooting out error and erroneous statements is one of the primary ways that science continues to create ever more current iterations of its practice.[79] Of course once an error is identified and addressed, it is seldom (if at all)

[79] See Giora Hon's "Error: The Long Neglect, the One-Sided View, and a Typology" in *Going Amiss in Experimental Research.* Hon constructs a taxonomy of experimental practice where error can be found in one of four distinct areas: 1.) Background Theory; 2.) Assumptions concerning the apparatus and its working; 3.)

mentioned again—maybe as an historical artifact—, so it is crucial for scientific rhetors in the nineteenth century to both discuss and eradicate error in their work.

For Rowland, the imaginative scientist is one who can engage productively—creating testable theories—by living with and orienting himself argumentatively towards an awareness of error and accuracy. The imaginative scientist moves beyond awareness and both orients the shape of the argument in response to each and creates the perception of it as well. The scientific mind must exercise error out of itself. The scientific rhetor must present this contradictory mental labor of excoriation of error, recognition of matters of precision, and movement towards accuracy. As a matter of argument, this helps do two things for the nineteenth-century scientist. It performs the search for error. However, it should be obvious by now that precision is constructed differently than accuracy. Precision, as defined by Hon, is about the closeness of measurements to one another and accuracy defines the closeness of the measurements to a physical reality.[80]

Observational Reports; 4.) Theoretical Conclusions ("Error" 22). She argues that the background theory is most like an argument in that it has assumptions about the experiment that shape the design and use of apparatus. She explains, "Errors indicate claims to knowledge. An error reflects the existence of an argument into which the physical process of the experiment is cast. It is this hidden argument upon which the claim to knowledge is based" (Hon, "Error" 21).

[80] For a discussion of modern nomenclatures of error, see Douglas Allchin's "Error Types." Allchin argues that error interrupts "work flow" (39). For Allchin, error is a result that can be responded to and addressed productively. Whereas, Daston sees error as a generative concept in science studies, Allchin sees error as an artifact of experimental practice that can be fixed. Citing Ian Hacking, Allchin argues for a conceptualization of scientific practice that looks very much like Daston's formulation of nineteenth century project (although I am not suggesting that they are the same thing being proposed). For Allchin, scientific practice is one that maps the world (41). When a map does not correctly predict the behavior of a phenomenon, it is in error. For Allchin, there are four levels of error that start focused on the specifics of the experiment and then move beyond to the larger practice of the field. He identifies them as Material,

Rowland's later career became synonymous with diffraction gratings and other mechanical measuring devices, and there has been some stellar work on the running themes of accuracy in his work. The diffraction gratings are important instruments and expressions of Rowland's scientific ethos, but two early articles by Rowland are useful for understanding his later, articulated stance towards his version of critical scientific practice could be considered as a mature reflection on the implied values in earlier practice. The evaluative topoi of accuracy and error reflect philosophical commitments that may not always be expressed through precision instruments.

If scientific imagination is necessary to produce new knowledge, then the first place that it must be applied is the ferreting out of error in scientific practice. Rowland is inordinately concerned with error and accuracy in his experimental practice and writing. In his scientific writing, he starts with his or another scientist's error as the primary starting place, and he consistently addressed error in other aspects of his practice. Accuracy and error are twinned topoi; one implies the other, and this nowhere more apparent than in Rowland's scientific writing. Moreover, error and accuracy are the two topoi central to Rowland's scientific practice, but more importantly, they are central to a scientific ethos that can make aesthetic judgments that satisfy both the reason and the imagination.

Observational, Conceptual, and Discursive. Material and Observational errors are the most local—happening at the level of the experiment—and the Conceptual and Discursive errors would track more with Kuhn's concepts of paradigms. In particular, I am interested in Material and Observational errors in that they most readily help rhetoricians understand the function of error in scientific argumentation. They are also the most generative when it comes to field specific arguments.

Ultimately, Rowland became known for crafting superior, accurate instruments—the diffraction grating—without which much of the scientific work in his field would not have been achieved. Although often noted for the equipment that he produced, as a rhetor Rowland was interested in demonstrating his understanding of the function of error and accuracy as topoi in his writing. In doing so, he replicates on the page, an imaginative practice that he advocates in his public speeches.

Evaluative Topoi as Inventional Strategy: "On Magnetic Permeability, and the Maximum of Magnetism of Iron, Steel, and Nickel"

Published in 1873 in the *Philosophical Magazine*, "On Magnetic Permeability, and the Maximum of Magnetism of Iron, Steel, and Nickel" uses mathematical formula, long sections of text, nine tables of measurements of magnetic strength, and two illustrations of measuring apparatus and the curves of magnetic influence to determine exact measurements of the magnetic properties of three common metals used in laboratory practice. Rowland explains that researchers "are able to predict how much an electromagnet will sustain without actually trying the experiment" (Rowland, "Iron, Steel, and Nickel" 53). The various formulas, tables, and charts support the accuracy of his statements, so that future research can rely upon his work rather than performing laborious experiments each time an individual researcher wishes to know the sustaining power of a particular electromagnet. For Rowland, accuracy was an elastic concept that included a range of activities in experimental physics from mathematical work to the crafting of measuring devices and demonstration machines. Rowland uses accuracy to describe his work, but accuracy is a fluctuating value for him. In this early paper, the evaluative topoi are powerful elements of scientific argument, and his responses to these topoi reflect the scientific ethos he describes in his public speeches.

Despite Rowland's focus on reproducibility of results in the text, this concern was not the original impetus for the paper. In fact, Rowland reports on his investigation into the distribution of magnetism on iron bars and steel magnets; however, this investigation turned into one concerned with magnetic permeability of substances. Rowland goes on to explain this shift in research as the result of trying to induce magnetism in iron and nickel:

> [I]n all theories of induced magnetism a quantity is introduced depending upon the magnetic properties of the substance, and without a knowledge of which the problem is of little but theoretical interest; this quantity has always been treated as a constant, although the experiments on the maximum of magnetism show that is a variable. However, the form of the function has never been determined, except so far as we may deduce it from the equation of Müller . . . which, as will be shown, leads to the wrong result. ("Iron, Steel, and Nickel" 35)

Rowland's conceptualization of accuracy is fundamentally important to his activity as a physicist; without it he cannot perform basic experiments. The lengths to which Rowland will go to be accurate strengthen his ethos as a researcher. In this article, his topic of magnetic permeability is secondary to accuracy; inaccuracy impedes his efforts to induce magnetism, which he understands to be more than a theoretical problem. Accuracy is the reason for embarking on this work, and it is the mode of doing the work as well. In Rowland's work, accuracy vacillates between reason and mode, and this shifting nature is used both as the basis for an evaluation of the importance of his work to the field as well as enacted through the tables and charts in his paper.

Accuracy is inherently linked to correctness in both scientific argumentation and in notions of rhetorical correctness and language facility, because the sciences stress the theory's ability to best model reality. As with Gibbs, Rowland is concerned with the ways in which theory and nature relate, but Rowland is much more willing in his writing to demonstrate the usefulness of inaccurate theory, and conversely, the limits of that inaccuracy in his work. Finally, Rowland is able to overcome the limitations of inaccuracy in this work by employing tables and illustrations, which allows him the theoretical and analytical freedom to work through the core aspects of his problem. It is this turn towards a rhetorical nature of scientific work that we see the creativity that he so readily celebrates as the work of the "pure" scientist as opposed to the commercial engineer.

Rowland's scientific ethos is structured in such a way as to be able to support rigorous inquiry but remain flexible enough to not be stymied by slight inaccuracies. In the article, Rowland explains that some error is inevitable when conducting scientific work, but as long as the error is small, "[scientists] can accept the results as approximately true" ("Iron, Steel, and Nickel" 37). He goes on to suggest that the new work he is engaging in, using Michael Faraday's work, will result in more accurate answers to the question of measurement of electricity in these elements. To this end, Rowland makes two arguments supporting his use of Faraday, both of which demonstrate the contingent nature of accuracy and error in scientific work: "Whether Faraday's theory is correct or not, it is well known that its use will give correct results; at the present time the tendency of the most advanced thought is *toward* the theory" ("Iron, Steel, and Nickel" 37). Here, Rowland argues for some variations on the concept of accuracy, so that accuracy, far from being an attribute of the physical world, becomes a communal activity reliant upon agreement by practitioners and its place in the activity of the scientist. Rowland's scientific ethos is flexible enough to support such a creation, and he implicitly connects it to a communal activity of knowledge making.

Accuracy can come in degrees; experimental results can be more or less accurate and more or less useful. Accuracy is also about the end use value of a set of data and not just the method by which data is acquired. Finally, Rowland argues in support of the accuracy of Faraday's method by claiming that the general move of most scientists in the field is towards an adoption of the theory. His oblique reference to the communal activity of theory and knowledge generation highlights the necessity the flexibility of a term like accuracy—itself not longer a stable, accurate term—but one that finds its accuracy in its flexibility. Rowland only starts with problems of known observations of the magnetism of these metals to begin a longer and more fruitful argument recording his measurements. In this way, using error and the drive towards accuracy, Rowland must replicate an ethos of the imaginative scientist. In this example, he is confronted with a problem that hinders his ability to make accurate determinations about magnetic phenomena. Confronted with this problem, he looks to the work of those before him (Faraday) but does not rely solely on this work when it is shown to have limited use. From that point forward, he creates a new approach to the problem using textual evidence familiar to professionals in his field. As a research scientist, Rowland must display an imaginative ability to adapt to situation, but he must also enact a rigorous and technical approach to the problem of error. Ultimately, the accuracy he purports to seek, in turn, becomes a provisional statement about the use value of his measurements. It is only the moral and technical aspects of the scientist (combined in an imaginative act) that authorizes him to make this statement.

Identifying Error: "On the Magnetic Permeability and Maximum of Magnetism of Nickel and Cobalt"

In the 1874 article "On the Magnetic Permeability and Maximum of Magnetism of Nickel and Cobalt," Rowland focuses on obtaining magnetic permeability for the metals nickel and cobalt. In doing so, he revisits his work from his earlier paper, and he attempts to correct an error he has discovered in his earlier mathematical reasoning. Furthermore, he discusses this error in a framework that explicates the two methods for determining magnetic permeability—the German method, which argues that two magnets can act upon each other at a distance *without* a mediating material, and the English method, which argues that two magnets need a medium in which to act upon each other (Rowland, "Nickel and Cobalt" 56). Rowland clearly prefers the English method; he calls the German method "absurd." However, he still finds analytical problems with the English method, which argues that "lines of force" connect objects at a distance. Rowland argues that the two different methods give rise to two different ways of looking at magnetic induction. In this paper, he argues for new understandings of the ways that magnetism works, and, in doing so, he also addresses a mistake he committed in his earlier paper. Using similar textual methods as the previous paper, he arrives at eight new laws "established entirely by my own experiments" (Rowland, "Nickel and Cobalt" 73). Finding error and addressing it is central to the work of the scientist, and it demonstrates an ethos based on technical prowess. Identifying error in one's own work is central to securing a moral ethos as well.

Rowland is quick to root out error in the work of other scientists and in his own as well.[81] He was considered quite the taskmaster while at Johns Hopkins, and his students were often terrified of his desire to root out error and ruthlessly point out flaws in their work. His work addressing error opens spaces for discussion rather than cutting down or diminishing the work of others. Although it could be understood as a gleeful attempt at uncovering the error in scientific work and presentation, Rowland's continual interjection of his notice of error supports an ethos based on the moral attributes of the scientist illuminated in his public speeches—he is driven to root out these errors as part of this work. In particular, he locates error within several defined and definite frameworks for doing scientific labor and for writing about it to an audience.

When directed towards his own work, Rowland's desire to ferret out error is immediately productive (rather than critical of other's work). In the first part of his 1874

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[81] See also Rowland's 1875 "Notes on Magnetic Distributions," where he calls readers' attention to a recent paper written by a Mr. Sears and Mr. Jacques in which they demonstrate the earlier findings of a Mr. Jamin are erroneous and resulted from a poorly constructed experiment that inadvertently measured the length of a rod rather than its magnetic permeability. The piece is short, but Rowland makes it clear that he finds the continual testing of theories and results a necessary part of the practice of a scientist. In particular, he notes, "Mr. Jacques is to be congratulated on pointing out these errors in M. Jamin's conclusions" (Rowland, "Notes" 81). Too much should not be made of this but to say that Rowland is most interested here in demonstrating that it should be celebrated when error is found in another's work. In this case, the error in Mr. Jamin's work did not further thinking in the field, and Rowland is excited to mention that his own error, which he discussed in future papers. In this short example, the error of another scholar is both a moment to celebrate the work of scientific practice—of rooting out error (as he discusses in other works) and for introducing his own work to create a more accurate method of measurement.

paper "On the Magnetic Permeability and Maximum of Magnetism of Nickel and Cobalt," he identifies the location of error in several different spaces. Each space is a rhetorical opportunity to intervene in his work and extend the discussion of scientific labor. In the first example, Rowland references his first paper on the subject, which was mentioned above—"In my former paper I assumed that ***B*** as well as ***J*** attain a maximum; but on further considering the subject I see that we have no data for determining which it is at present" ("Nickel and Cobalt" 57). From this point, Rowland uses his own mistaken assumption to produce an opening to discuss his own work in attempting to measure the magnetic permeability of nickel and cobalt, but he is also much more careful in this paper than the first when explaining sources of possible error in his work.

Contextualizing the source of error is an important part of addressing this evaluative topic. In this paper, Rowland explicitly explains to the reader "The experiments in this paper were made at such odd times as I could command, and the first ones were not thoroughly discussed until the series was almost completed; hence I have not been so careful to guard against error as I shall be in the future" ("Nickel and Cobalt" 59). In noting the source of error in his work, Rowland demonstrates a commitment to a scientific ethos constructed through the moral standing of the scientific rhetor. Regardless of the possibility of error in his work and the real issues with constructing machines that could measure magnetic (and later optical) phenomena without interference, Rowland needed to sustain his moral standing as a scientist who roots out error and who must also accept an amount of erroneous data in order to move forward with theorizing. So, returning to the example of his paper on nickel and cobalt, we see Rowland pivoting on his concept of error to explain to the reader that some error will creep into scientific work, and that this is inevitable: "[T]he results which I have obtained . . . are still so novel that they must possess value notwithstanding this defect; for they contain the only experiments yet made on the permeability of cobalt at ordinary temperatures, and of iron, nickel, and cobalt at high temperatures" ("Nickel and Cobalt" 59-60). For Rowland, error is both something to be deployed as a space for new intervention and an element of scientific practice that must acknowledged and defended against in writing. Indeed, towards the end of this paper, he again remarks upon the value of his work explaining that because of its one of a kind status as first in his disciplinary field means it "possess[es] at least a transient value" (Rowland, "Nickel and Cobalt" 67). My claim here is not meant to over-emphasize this move, but it does suggest that Rowland was deliberately attempting to address his conception of error in his work in an effort to demonstrate that it held value not as an unassailable argument but as the beginning stages of a new line of inquiry.

Rowland makes use of a method from natural science to bolster his exhaustive cataloguing on the magnetic permeability of cobalt and nickel. Immediately following the sections that note the error in his work and the acceptable level of error in his equations, he spends quite some time away from his mathematical and technological descriptions to produce a lavish (and quite out of character for his writing) description of the materials he uses:

> The cobalt was quite hard, but turned well in the lathe, long shavings of metal coming off and leaving the metal beautifully polished. The metal was slightly malleable, but finally broke with a fine granular fracture. The rings when made were slightly sonorous when struck; and the color was of a brilliant white slightly inclined to the steel-color, but a little more red than steel. . . . When the rings were struck, they gave a dead sound as if made of copper. . . . There is great liability to error in taking the specific

> gravity of these metals, because they contract so much on cooling, and unless this is carried on rapidly crystals may form, between which, as the metal contracts, vacant spaces may be left." (Rowland, "Nickel and Cobalt" 60)

This section demonstrates a moment in the article that strikes the rhetorician of science because it more closely resembles the writing aligned with natural philosophy than with physics. When compared to other information gathered by Rowland and presented in the paper, the descriptive paragraph above seems even more out of place. Immediately following this section is an exacting account of his measurements in the form of a table, which recorded the weight of the samples, water loss due to heating, specific gravity, and mean diameter of each sample.

The description, then, serves to enact an earlier version of accurate science that speaks to both the moment in which Rowland responds and the demands that addressing error make upon the scientific rhetor. Here, the tables and mathematical proofs are not enough for Rowland, and he deploys the descriptive passage as a way to enact an earlier type of science. This comes in part because his work is such a hybrid of mechanical engineering, mathematical theorizing, and metal working in a fashion akin to the natural scientist that he can draw from the different writing genres associated with each field to cobble together his work. But, he must also address the function of error and accuracy in each one.

Rowland repeatedly mentions the presence of error in his work, but makes reference to "experiments" that he has performed which convince him of his accuracy. In the first example, from "Nickel and Cobalt," Rowland "satisfies himself" that his results are correct (70). In the second example from a much later paper "On the Ratio of the

Electro-static to the Electro-magnetic Unit of Electricity," Rowland states, "I satisfied myself by suitable experiments that the error from this cause might be neglected" (273). This suggests that he finds his work and his estimation to be central to his project. Like the earlier formulation of the scientist as most qualified to judge and measure nature, he is the arbiter of his own work. But, having now established himself as reliable rhetor, he can make such comments to support claims of accuracy.

In this example, ethos is constructed through a methodical approach to error in determining magnetic permeability in cobalt and nickel. In naming all three earlier attempts to explain this relationship, Rowland locates his work within an intersection of prior efforts at theorizing the effects of magnetic permeability. Furthermore, he uses erroneous and inaccurate aspects of the earlier work to clear a space for his work in the article that results in the eight laws at the end of the paper. As with the earlier paper, Rowland uses the evaluative topic of error and accuracy to start his work in theorizing the relationships of magnetic permeability more usefully than has been accomplished previously. In this particular example, he also triangulates a kairotic moment and launches his work in an effort to address inaccuracies from prior work.

The Imaginative Response of Evaluative Topoi

The evaluative topoi, or themata, of Rowland's physics, error and accuracy, necessitated a scientific ethos flexible enough to address these topoi successfully, and through that act sustain a scientific ethos of moral and technical prowess. In particular, the formulation of imagination plays a central role in Rowland's conceptualization of a critical scientific practice. Although he seems highly suspect of the value of imagination in scientific practice (as evidenced by the quote above), he does see it as a central faculty for the highly successful scientific thinker who exists in relationship with other scholars. In "The Highest Aim of the Physicist," Rowland sees the communication of scientific practice as central to the value of scientific research:

> A hermit philosopher we can imagine might make many useful discoveries. Yet, if he keeps them to himself, he can never claim to have benefited the world in any degree. His unpublished results are his private gain, but the world is no better off until he has made them known in language strong enough to call attention to them and to convince the world of their truth. (669)

Useful discoveries must be shared in such a fashion that the audience can be convinced of the theory's correctness. Language plays a central role in this activity, and Rowland understood that. Moreover, he understood that the scientist always stood in relationship to others in his field and the larger community, and the fact of this relationship placed a great responsibility on the researcher to make the best use of his imagination to come to productive conclusions about the world.

Rowland's formulation of the function of imagination in the critical process of scientific practice closely matches the function of imagination in the then commonly taught rhetorical practice of the nineteenth century. Far from being a minor coincidence, this alignment of scientific and rhetorical practice suggests that scientists were clearly aware of the communal nature of their work. Although the imagination is considered a faculty of the individual, the ways in which the Scottish New Rhetoric and Rowland formulated its role suggests it was a critical component in evaluating textual claims. Recognizing imagination's centrality in both practices points to the need to articulate its position as a faculty central to the formulation of extra-empirical values as well as traditional empirical values. Doing so demonstrates how overarching cultural values obtain within scientific practice. Moreover, those extra-empirical values are crucial for deploying evaluative topoi in scientific argument.

Although there are important aspects of scientific research methodology that Rowland addresses, the well-regulated imaginative mind is central to his conception of practice that hinges on negotiating the evaluative topoi of error and accuracy. Through an understanding of imagination's role in these operations, rhetoricians can better formulate how an aesthetics of science enters into scientific conversations, so that what would seem to be statements of personal preference can be legible to scientific audiences as statements of community values grounded in empirical practice. To that end, evaluative topoi, as presented by Prelli, are important for exploring this mechanism. Prelli's work on ethos and topoi provide a foundation for the discussion of values in scientific arguments that can move beyond individual preference. Imagination is the critical tool by which the scientific rhetor can determine the appropriate critical stance to take towards error and accuracy. This critical faculty assists the rhetor in identifying the appropriate topic to start a piece of writing.

The resource intensive nature of physics meant that scientists had to spend significant energy securing funds for their continued work. Rowland was no different in this regard. As has been mentioned, it was a main concern of his as well. His articulated framework of regulated imagination both informs his laboratory and rhetorical practice and gives him useful topoi for communicating the value of practice over and above the value of more "practical" research. In this way, he attempts to express its larger cultural value to lay audiences. The artistic merit of physics is translated into an imaginative practice, which also regulates the experimental and rhetorical practices of scientists.

An aesthetic response to scientific writing or knowledge is assumed to be a clear statement of appreciation of some aspect of the phenomena. What we see with Rowland is that an aesthetic of science is created through both a formulation of scientific ethos and through an enactment of different evaluative topoi in scientific argument. This point is significant because it opens up a space where rhetoricians can explore how non-rational arguments are really very rational arguments located within evaluative topoi. These arguments can be deployed both in scientific writing (i.e. experiment reports) and when explaining the need for more funding. In the case of Rowland's aesthetic, his approach to scientific ethos informed his writing, and in turn served as persuasive support for his continued exploration of the imaginative scientist. But, it is the imaginative scientist who possesses both the moral and technical ethos necessary for making evaluative judgments in his practice and writing. Above all, as Rowland, repeatedly explained to his listeners and readers, this relationship between ethos and topoi obtained only within the act of communicating research to others. Acting within a community of practice towards a greater understanding of nature both necessitated and authorized this relationship. The theories of the "hermit philosopher" do not affect our understanding of nature because they do not circulate. If it is through this circulation of theories that Rowland believed researchers knew the world, then surely reason and imagination were a central part of that process.

CHAPTER 5

CONCLUSION: SCIENTIFIC ETHOS AND AESTHETIC JUDGMENT

Scientific ethos relies on demonstrating the faculty of judgment to one's audience, and aesthetic judgment is part of the larger scheme of evaluating activities that a scientist undertakes during his research practice. Demonstrating appropriate judgment is central to creating scientific ethos, and in the nineteenth century, appropriate scientific ethos was critical. The new research institutions and disciplinary groups in the United States effectively rearranged older models of personal relationships among scientific researchers, and the audience for scientific theories was spread across the nation and held a variety of disciplinary and institutional allegiances. In this context, scientific ethos demonstrated, in part, through aesthetic judgment became increasingly important for scientific argumentation.

Although the capability to write persuasively appears to be unrelated to the technical skills necessary to be a successful researcher, performing aesthetic judgment signaled allegiance to extra-empirical values of scientific practice. This practice was not accessible by the audience, so aesthetic values, in turn, were necessary for structuring arguments for consumption by an audience. In this regard, the faculty of taste was of paramount importance, and it was taught explicitly in nineteenth-century rhetoric textbooks and classrooms. Rhetorical scholarship and teaching in the nineteenth century was uniquely positioned to help cultivate a critical language that supported an examination and analysis of the rhetor's ethos as expressed in written argument. The concepts of taste, simplicity, brevity, and imagination were tools for analyzing written work and the writer—well-crafted arguments were signs of well-trained individuals.

Aesthetically pleasing elements in a composition signaled the intellectual abilities of the writer. In particular, taste was a key way of understanding and evaluating the ethos of the writer—his ability to judge. For Josiah Willard Gibbs, concerns about simplicity and brevity in his writing demonstrated his focus on his ability to judge the presentation of his complex argument so as to create a “well-ordered garden” of mathematical theory. For Henry Rowland, imagination was a central part of the critical faculties that a successful scientist should possess and nurture; it was the ability to adapt flexibly to the exigencies of scientific research—the always-present errors and incessant demand for accuracy. For both Gibbs and Rowland, we can trace these terms and concerns to their rhetorical education in the Scottish New Rhetoric, the foundation for rhetorical scholarship and education in nineteenth-century American universities. In doing so, I link a language designed to decipher the judgment of the writing student with the language used to understand the faculty of judgment in the scientist. Aesthetic judgment, in these terms, is akin to scientific judgment in that it allows for an understanding of the interior workings of the scientific mind through the written word.

The use value of aesthetic judgments is a necessary part of their inclusion in arguments. Judgment is the central act that performs compliance with a wide variety of values located within an aesthetics of science, and appropriate displays of aesthetic judgment demonstrates the rhetor’s allegiance to extra-empirical values that are useful in producing disciplinary knowledge. Since the aesthetic judgment is valuable to persuasive arguments, we must think of them as rhetorical artifacts; however, they are not ornamental elements of scientific arguments. Aesthetic arguments do critical work in crafting the rhetor’s ethos, and they also help generate a shared sense of communal values within disciplinary community. These communal values must also speak to the technical work of the researcher.

Addressing the connection between aesthetic concepts and technical argument has required that we shift our focus to the act of judgment itself as an aspect of scientific ethos. The terms and values expressed are contextual and shift from one discipline to the next and from one generation to the next, but the value placed on the ability to judge is the eternally present component to an aesthetics of science. Judgment, as a demonstrable act, is the true focus of aesthetics in scientific argument. Demonstrations of judgment come in many forms, and aesthetic judgment is as much dependent on more technical forms of judgment as technical judgments are on the demonstrations of aesthetic judgments. The productivity of an aesthetic argument must be both rhetorical and technical; the terms used and the values expressed describe elements of the argument and of the technical work of the scientist. Aesthetic judgments authorize productive work and guide the presentation of that work to a disciplinary audience.

By studying the relationship of the rhetorical and the technical in scientific rhetoric, we begin to understand how extra-empirical values can be useful when it comes to highly specialized discussions that require the rhetor and audience to focus on technical and scientific ethos as fundamentally important to professional competence. Alan Gross and Lawrence Prelli respectively have discussed the importance of scientific ethos in their work. For Gross, ethos speaks to the social context in which the rhetoric of science is conducted; the rhetor must be aware of and speak to social conventions as much as disciplinary conventions. Prelli argues that ethos is generated through adherence to certain topoi of argumentative invention. Both understandings of ethos' importance touch upon the multiple ways that ethos can be constructed and maintained in an argument. The purpose of this dissertation has been to tease out those embedded connections so as to demonstrate the ways in which aesthetic arguments in scientific rhetoric speak to the relationship between scientific practice and presentation in writing.

Connecting scientific practice with presentation required a lexicon that could describe the interior activities of the scientific writer. In the nineteenth century, rhetorical studies was in a transitional state—moving from a tradition defined by the faculty psychology approach of the Scottish New Rhetoric to a Current-Traditional approach which emphasized utility and correctness. Along with the changing focus of the rhetoric classroom, there were changes in the goals of writing instruction, which many scholars, like Michael Halloran, have noted shifted from an oratorical to a written composition. The focus of writing became more personal and less public. However, many terms and ideas that speak to the interiority of the rhetor remained intact in discussions of compositional practice—bringing the personal into the public in unexpected ways. These terms became static abstractions and entered into the lexicon of compositional discourse—the discourse about how to compose arguments. In particular, taste became a way to think about the rhetor's ability to judge the appropriate way in which to present material to an audience—it also became a term that had critical significance and was used to determine the abilities of the rhetor as a presenter. These ideas connect to scientific rhetoric and the conceptualization of what it meant to compose arguments as a scientist; the technical knowledge of the Josiah Willard Gibbs and Henry Rowland was made legible to audiences through their writing, and it was their productive compositions that are central to this dissertation.

In the nineteenth-century, taste was a particularly important term used to understand the faculty that perceived the natural world and re-ordered those perceptions in an effort to compose arguments. By studying the rhetorical training of Gibbs and Rowland, we have gained insight into the processes by which they think about their work as rhetors, and we see how aesthetic judgment is part of a scientific ethos. Indeed, their writing suggests that the relationship between scientific ethos and aesthetic judgment is rhetorical in nature. The approaches to argument and presentation demonstrated in their respective pieces point to the philosophical underpinnings of how subjective aesthetic judgment can also be an important part of argumentation based in objective knowledge production. Taste was the faculty that rhetors focused on in their efforts to train students in their ability to understand the world and make that understanding legible to an audience through appropriate displays of judgment. Judgment is central to scientific practice and aesthetic judgment is performed in their pieces as a way of demonstrating their facility with extra-empirical values. By doing so, the values also have use value in their respective fields. This use value is real, but must be performed rhetorically through writing.

For Gibbs, simplicity is an aesthetic concept that appears in his writing as he comments on his own ability to present abstract, mathematical arguments to an audience that most likely was unfamiliar with the fundamental aspects of his work. His drive to simplify his work directly reflects his concerns over how his work is received by his peers, but it also speaks to longstanding mathematical concerns about the efficacy of the discipline. Furthermore, simplicity is linked to coherence in his work, and the impetus to generate coherent arguments is driven both by the need to simplify argumentation for an audience and to generate useful models that predict the phase state changes of matter. The difficulty for Gibbs was the abstract nature of his work and the shape of the disciplinary boundaries during his career. There did not exist a well-developed mathematical or research oriented graduate program in the United States in the early part of his career, and he found himself mainly addressing his immediate peers at Yale University and the Connecticut Academy of Arts and Sciences. Due to the constraints placed on him by his immediate audience, he was forced to consider methods of presentation that would productively enhance his theoretical work and demonstrate his commitment to extra-empirical values. His use of the metaphor of the permeable membrane speaks to his understanding of the useful images already in circulation. In both cases, we can infer that some of the philosophical grounding for his work can be found in his rhetorical training during his undergraduate years at Yale, where he used Richard Whately's *Elements of Rhetoric*. In these instances, aesthetic components of his argument are best understood through his rhetorical training. Whately directs students to a more nuanced understanding of themselves as rhetors responsible for constructing arguments and generating comprehensible arguments. In Whately's formulation, presentation is different than the original research—arrangement is the central concern of the rhetor, and Gibbs repeatedly discusses this concern in his work. Gibbs' overarching rhetorical responsibility was to explain his complex material to a varied, unknown and heterogeneous scientific audience; the presentation of his argument was as important to him as the accuracy and correctness of his math.

For Rowland, scientific ethos was created through a complex negotiation of the scientific self and the imaginative self. Scientific ethos was created for an audience by performing the imaginative self as a response to the evaluative topoi of accuracy and error. In both of the articles I examined, he enacts a flexible approach to his own work that demonstrates an imaginative, technical ability to solve problems. This ability is surely a technical one, but Rowland must also demonstrate it rhetorically in order to make his interior, scientific self legible to his audience. In doing so, he generates more support for his work in physics. This was especially important for him as an individual scientist and for his field as it struggled to find a foothold and grow as a discipline in the latter half of the nineteenth century in the United States.

The imagination, as expressed by Rowland, is best understood as central for constructing ethos. Using Quackenbos' generic understanding of imagination helps rhetors understand that this aspect of scientific ethos is filtered through rhetorical practice and, as such, reflects a way of reconfiguring the factual data of the world. The rhetorical imagination is part of a suite of faculties that perceives the natural world, analyzes the elements and synthesizes those elements into a new argument. Furthermore, imagination's centrality to composition spoke to both the composition as a sign of that imagination. Unlike Gibbs, Rowland undertook his research work within the context of a more robust and growing community of scholars in physics. His understanding of scientific ethos was directed at establishing a communal understanding for how to best proceed as a newly constituted scholarly group.

In both examples in this dissertation, aesthetic judgment produces communal knowledge through an engagement of extra-empirical values. Unlike Thomas Kuhn's claim that aesthetic arguments reflect longstanding beliefs in a given field, these two examples suggest a more nuanced understanding of the relationship between aesthetic judgments and scientific argument. Furthermore, my work extends the argument that aesthetic values are extra-empirical. My research places the focus on the rhetor's relationship with their audience and the exigencies of their particular historical moment. In doing so, I recognize that the true judgment is being left to the audience—they judge the rhetor's ethos. This judgment is based in both technical and rhetorical skill displayed by the individual scientist and how that display aligns with the implicit and explicit understandings of what constitutes scientific ethos. In this way, the objective mode of research is assimilated with the subjective aesthetic judgments in a rhetorical practice that demonstrates production of useful knowledge. The tightly bound display of objective and subjective practices is often elided when a scientific work is considered—focusing mainly on the technical material as the true product and ignoring the aesthetic judgments inherent in the successful presentation of that material. However, the technical material is made possible through the appropriate aesthetic judgment of the rhetor. During the nineteenth century, this was particularly important due to the centrality of the written word as the primary means of communicating ideas.

Although the central act investigated in this dissertation is demonstrations of judgment, scientific ethos is central to an understanding of the importance of the act of judgment. This dissertation has begun the process of exploring how extra-empirical values also give us insight into the scientific ethos. These extra-empirical values speak to both disciplinary values and societal values; they speak to both the larger context and the appropriate areas of what can be said within scientific discourse. In the end, aesthetics and aesthetic judgment in science are useful in revolutionary science and other times of change in scientific history, and they are useful for the more political tasks of creating and maintaining a community of scholars. The seemingly contradictory adherence to objective modes of production (themselves subject to historical forces) and the subjective mode of value judgments of aesthetics are joined in the production of generating scientific ethos. This productive joining points us to a continued examination of the structure and function of the scientific self in scientific argument.

There are two fruitful areas of study suggested by the conclusions drawn in this dissertation. The first area of study is the productive value of aesthetic judgment in scientific argument. If aesthetic judgment speaks to something more than ornamental elements of argument, then rhetors can study scientific arguments that are simultaneously aesthetically persuasive and adhere to the technical standards set by a particular scientific discipline. Exploring this area would help us further define the place of aesthetics in scientific argument that speaks to a variety of possible exigencies of disciplinary changes as well as institutional and cultural contexts of scientific argument. The second area of research could come from further studies of scientific ethos. Clearly, there are several avenues of exploration with this element of scientific argument, and aesthetic judgment is but one. The central scientific act, which must be made legible to the audience, is that of judgment, and scientific ethos is founded on that act. However, it is not solely constituted by that act; there are other elements of ethos that help produce successful arguments that address a multitude of topics.

Aesthetic judgment in science is an elusive object of study precisely because it confounds the common understanding of the basis for the acceptance of sound arguments in scientific discourse. Aesthetic judgments would seem to be subjective and outside the area of interest for scientific rhetors, yet these judgments can be central in producing acceptable knowledge within a particular field. Focusing on demonstrations of judgment untangles the connections between aesthetic judgments, data, and theoretical statements. Demonstrating judgment is about creating ethos rather than arguing from logos—about making one's interior self legible as a way to make an argument persuasive. During a period of institutional and disciplinary change in nineteenth-century America, aesthetic judgment was used in scientific arguments to bridge the gaps created by newly formed disciplines operating within newly changed national and international institutions of science. The geographically dispersed nature of scientific communities in the nineteenth century demanded rhetorical interventions to demonstrate scientific ethos. Those interventions came in the form of aesthetic judgments, which discussed more than they seemed to at first, demonstrating that scientific ethos and aesthetic judgment are inextricably entwined.

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