ABSTRACT

Over fifty years have passed since C. P. Snow observed a crucial divide between practitioners and scholars in the arts and sciences; however, at the beginning of the twenty-first century, far from the isolated "two cultures" he perceived, the dialogue between science and literature has been well established. The past ten years have seen an increase in plays overtly incorporating complex scientific issues as subject matter, eliciting comparisons between the goals and methods of scientific inquiry and dramatic writing. These "science plays" engage issues ranging from biology and mathematics to quantum physics and medicine, using to varied effect a wide range of characters, structures, and styles.

Plays such as Bertolt Brecht's *Life of Galileo*, Friedrich Dürrenmatt's *The Physicists*, Tom Stoppard's *Arcadia*, David Auburn's *Proof*, and Caryl Churchill's *A Number* have caught the attention of both scientists and the theatre-going public around the world. They demonstrate the possibility of bridging the gap between specialists and the layperson, and creating theatre that is both scientifically complex and dramatically appealing.

Michael Frayn's recent play *Copenhagen* provides an ideal example for examining the wide realm of possibilities, benefits, and dangers of combining the two disciplines in dramatic literature. Frayn tells the story of Niels Bohr and Werner
Heisenberg, close friends and pioneers in the field of quantum physics in the early twentieth century. Heisenberg, a German, and Bohr, a Danish Jew, found themselves on opposite sides of World War II, racing to create the first workable nuclear weapons. 

*Copenhagen* dramatizes a mysterious 1941 encounter between the two men, at the height of the war, in Copenhagen. Scholars, historians, and scientists still debate the details of that meeting, but the result of it was the near-dissolution of the powerful friendship between teacher and student. Using theories attributed to them, such as the uncertainty and complementarity principles, Frayn attempts to reconstruct that meeting in the presence of Bohr's wife, Margrethe. The three characters discover that human thoughts and motivation can be as elusive as subatomic particles, and the audience witnesses the worlds of science and drama in pursuit of the similar goal of discovering the truth.

What *Copenhagen* and other science plays demonstrate is both the extent and limits of understanding human beings through the scope of science and literature. The combination of the two disciplines into these "science plays" proves mutually beneficial, as drama discovers powerful new subject matter and science uses the medium as a teaching device.
For Beth
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CHAPTER 1

INTRODUCTION: THE DISCOURSE OF SCIENCE AND LITERATURE

"Mathematics becomes very odd when you apply it to people. One plus one can add up to so many different sums...." – Heisenberg

1.1 INTRODUCTION

Science and all its subcategories are not new to the stage. As recently as 2002, Harry Lustig and Kirsten Shepherd-Barr recorded the opening of more than twenty new plays on a scientific theme over the previous five years. That number has undoubtedly grown since then. Even a brief glance at theatre listings and records reveals a large number of shorter plays and sketches written for performance in classrooms, museums, and other educational institutions, turning scientific experiment or discovery – often rather simplistically – into drama. Neither is science new to examination as performance. One can trace studies back to the quacks and mountebanks of European history who treated surgery, dentistry, and other practices as varieties of performance and opportunity to cash in on an audience's curiosity.

With the exponential growth in technology attributable to the Scientific Revolution, and the emergence of the scientific method and its artistic parallel of naturalism in the late nineteenth century, drama has had a worthy, new subject. The
thrill of discovery and pioneering new techniques, the unique personalities behind them, and the perception of a select coterie who understand the discipline lend themselves readily to dramatic representation. The ethical ramifications of budding technology and humankind’s ever-changing relationship to it offer appealing subject matter as well. In short, science can make for an interesting play.

Science established a firm footing in drama even before the twentieth century. Christopher Marlowe and Ben Jonson during the Renaissance vilified and lampooned the early scientific profession’s claims to knowledge with Dr. Faustus and The Alchemist, respectively. In the nineteenth century, Johann Wolfgang von Goethe’s retelling of Faust and Frederick Büchner’s Woyzeck again cautioned against the reckless pursuit of knowledge. The twentieth century has given us an abundance of plays dealing exclusively with science and its practitioners, treating them with a variety of attitudes. At times plays express trepidation over scientific discovery. Frederich Dürrenmatt’s The Physicists, for example, portrays the consequences of irresponsible use of scientific knowledge. George Bernard Shaw’s The Doctor’s Dilemma and Henry Arthur Jones’ The Physician question the effectiveness of medical practice and its true depth of comprehension.

Other plays celebrate the discoveries of science and the people making them. Carl Djerassi’s and Roald Hoffman’s Oxygen debates the discovery of the title element. History goes on trial through the scope of the present, as modern day scholars and scientists argue about who actually made the breakthrough. So, too, with Michael Frayn’s Copenhagen, which again views history in hindsight, as three historical characters relive the beginnings of the atomic bomb. Tom Stoppard does the same in
*Arcadia*, but on a fictional basis. Not only do his characters discuss chaos theory, but they also happen upon a fictional character who discovered it in 1803. Stoppard likens a shift from traditional to complex mathematics to the swing from Enlightenment to Romantic sensibilities. Each of these plays explores the scientist’s relationship to the world. Bertolt Brecht’s famous Galileo, for instance, faces the consequences of challenging social and religious norms with new scientific thought. Catherine, in David Auburn’s *Proof*, weighs the burden of using her inherited genius and madness to further mathematics. The list goes on throughout the century, from around the world, and includes full-length plays, one-person shows, even musicals.

The focus of my study will be the “hard” sciences – mathematics, physics, chemistry, biology, medicine – as opposed to the “social” sciences – sociology, psychology, economics. I choose this focus because of their increasing inclusion in dramatic writing, more prominently than the social sciences. As the twentieth century progressed (and progresses into the twenty-first) the hard sciences, in part, moved away from the rigors of the scientific method and incorporated theories questioning the reliability of knowledge and quantification. Einstein’s famous theory of relativity postulates the difficulty of measurement, predominantly at high speeds. Werner Heisenberg introduced quantum mechanics and the uncertainty principle in physics, questioning the absolute specificity of position and velocity at the atomic level. Chaos theory, sometimes attributed to Mitchell Feigenbaum, attempts to mathematically describe nonlinear systems in nature. Scientific endeavor has been deconstructing ideas
of perfect causality and absolute determinability. At its heart, science continues increasing our depth of knowledge and stimulating our understanding of the incredible mysteries that may never be solved.

A number of definitive studies have already established a firm interdisciplinary relationship between literature and the sciences. Books such as Damien Broderick’s *The Architecture of Babel* firmly close the gap articulated by C. P. Snow in *The Two Cultures*. I agree wholeheartedly with Broderick in saying that the relationship is mutually beneficial, so it is not my concern to establish, challenge, or redefine the discourse. Instead, I prefer to take up Broderick’s (and others’) concern to unite the two cultures and examine how practices in playwriting aid the process. How specifically do playwrights such as Michael Frayn, Tom Stoppard, and Caryl Churchill bridge the gap and make esoteric scientific premises comprehensible to the uninitiated? Is it through recognizable characters, accessible dialogue, or effective metaphor? Or do they fail? Have they only confused scientific language and misused the range of metaphors available? At the heart of my work lies the question, “What – if anything – constitutes an effective use of overt scientific topics in dramatic literature?” What makes a good science play?

1.2 OVERVIEW OF CRITICISM AND THEORY

Even as late as the 1950’s, C. P. Snow famously divided science and literature into “two cultures.” Snow observed a deep gulf between scientists and literary intellectuals, citing specific examples of different scholars’ in comprehesion of the other’s language.¹ Snow concerned himself primarily with education in Britain, but he
expands his discussion to the fields of science and literature at large. Glynne Wickham, like Snow, surveyed scientists' and artists' inability to understanding each other's realm and its effect in the world. Both Snow and Wickham feared the limits of specialized education, worrying that their university departments would churn out more students incapable of interdisciplinary research.

Snow, however, acknowledged the coming of a third culture. This third culture could engage "cardinal problems — such as the human effects of the scientific revolution" and includes such intellectual disciplines as "social history, sociology, demography, political science, economics, government, ... psychology, medicine, and social arts such as architecture." Although he still perceived scientific and literary studies separated in their cultures, he at least saw the foundation of a bridge between the two. He assumed the two cultures would remain incompatible for only so long.

Contemporaneous with Snow, Oscar Cargill prescribed how writers could correctly engage the realm of science. In his 1951 article in College English he warns of several misappropriations of science in literature and provides recommendations for a proper relationship. He cautions writers against using science to accommodate contemporary moods and beliefs, as well as using it as a backdrop to the action. His biggest bone to pick is with writers (and he includes dramatists) infatuated with popular, perhaps temporary, scientific concepts that turn worthy characters into mere spokespersons. He takes Eugene O'Neill and Sydney Howard to task for undermining some of their characters as exhibitions of Freud's latest theories. Instead, Cargill asserts, the writer and the scientist should espouse a worldview capable of change, far from a fixed utopia, but a flexible one which advocates "methodical skepticism.... The
truth,” he says, “which needs most vending today by creative writers is that a world of change and flux ... is the only world in which art and science have any immortality.”

G. S. Rousseau’s 1978 article in *Isis* attempts a summary of the science-literature discourse from 1950 to 1978. Rousseau’s work seems quite reliable, despite including one of his mentors in the discussion, and he admits that the myriad critical approaches to the field usually result in an impasse. This is true, he asserts, of the relationship between scholars researching the influences of science on literature and vice versa, as well as scientists and writers of that “great anomaly,” science fiction. Rousseau evidently disdains structuralism and its tendency to encourage an approach that merely says, “the more self-reflective the better.” He finishes with a brief description of the current “critical pluralism” of the field, which tends to deflect serious students by invalidating science and literature as a definable field. What Rousseau and many other scholars see in the field of science and literature is more than a gathering of literary references to scientific terminology and metaphor, but a mutually beneficial conversation.

Recent critical discussion detects a strong discourse between literature (not to mention art in general) and science. Books such as the complicated *The Architecture of Babel* (1994) by Damien Broderick review the complex history of the relationship. One volume receiving much critical attention is *Chaos and Order: Complex Dynamics in Literature and Science* (1991), edited by N. Katherine Hayles, a collection of essays focusing on the dynamic of chaos theory and literature. Hayles’ introduction offers valuable insights to the broader field, with further cautions about the mutual use of language and metaphor.
Even the very nature of twentieth century science encourages interdisciplinarity. James Gleick, in the prologue to his *Chaos: Making a New Science*, quotes a Navy official in charge of scientific financing: “Fifteen years ago, science was heading for a crisis of increasing specialization. ... Dramatically, that specialization has reversed because of chaos.”¹¹ The applications of chaos theory span such varied fields as mathematics, biology, physiology, economics, and meteorology. Gleick also discusses the effects that theories such as Einstein’s relativity and Heisenberg’s uncertainty have had on interdisciplinarity, and how other disciplines besides science have embraced those theories.

A number of other studies also scrutinize the effects of scientific development on art in general. Daniel McDonald’s 1967 article “Science, Literature, and Absurdity” summarizes the development of absurdism as a response to science’s challenges to views of reality. George Kurman pinpoints the loss of classical tragedy and the rise of modern tragedy to an increased cultural awareness and sensitivity to the concept of entropy. Likewise, Leonard Shlain devotes his entire book *Art and Physics* to describing parallels between breakthroughs in physics and art.

David E. R. George turns to quantum physics for a new model for theatre itself. He views the Theatrum Mundi model – “All the world’s a stage” – as not only outdated but harmful to the theatrical paradigm, for it devalues theatre as an exemplar of the “insincerity, deception, and illusion it locates in everyday life.”¹² Seeing the similar goals of art and science as positing “activity and behavior of observed phenomena,” George articulates how the Spectator, Space/Time, and the Actor in both quantum physics and theatre result in a realm of potentiality.¹³ Potentiality in quantum physics
stresses that subatomic particles’ whereabouts are known only in statistical probabilities. Similar probabilities exist in the realm of theatre, George observes, since one particular production is the reduction of all probabilities, such as choices of movement, inflection, and interpretation, into one actualization which is, in turn, shadowed by all remaining possibilities. This concept has already been expressed by Marvin Carlson, amongst others, observing that all probabilities of space, actors, text, and audience, both past and future, “ghost” any theatrical performance.$^{14}$

By now the point is clear. Scientists, literary theorists, and many in between have engaged in an active dialogue between the varying disciplines of science and theatre. Certain pieces of writing have received more attention than others – sometimes rightfully so, sometimes not – for their discussion of a particular issue or from a particular angle.

1.3 A FOCUS ON COPENHAGEN

To demonstrate the thriving relationship between science and literature, I have chosen to examine Michael Frayn’s 1998 play Copenhagen, which dramatizes the lives of physicists Werner Heisenberg and Niels Bohr, two central figures in the development of modern physics and the first atomic weapons. I have chosen Copenhagen in part because of its recent popularity and status as a benchmark “science play,” but primarily because of the conversation that Michael Frayn and others have engaged in because of it. I wish to draw a central comparison between the goal of knowledge and the goal of the playwright. In a similar vein, Broderick quotes from Lewis Thomas:
We have a wilderness of mystery to make our way through in the centuries ahead, and we will need science for this but not science alone. For getting a full grasp, for perceiving real significance when significance is at hand, we shall need minds at work from all sorts of brains outside the fields of science, most of all the brains of poets, of course, but also those of artists, musicians, philosophers, historians, writers in general.\textsuperscript{15}

Borrowing Thomas’s phrase, I believe we can draw a strong parallel between the scientist’s and playwright’s efforts at navigating the “wilderness of mystery.” Despite George’s objection, comparing the stage to our world suggests that our attempts to locate the human being’s place on the stage parallel the act of doing so in the world.

Another reason I have selected \textit{Copenhagen} is its extensive preoccupation with epistemology. Frayn focuses on the nature of the implicated observer, which Broderick parallels through Collins’ and Pinch’s discussion of the scientific community and the need to learn the language of science, and thus be implicitly involved in the observation.\textsuperscript{16} I will discuss Frayn’s considerations of the nature of the observer later.

Broderick also frequently references dialogue regarding the nature of laboratory experiments. I believe his comments expand upon Heisenberg’s uncertainty principle and draw a larger metaphor with scientific experiment. Broderick quotes Karin Knorr-Cetina in observing the laboratory as a constructed version of nature. Every element has been planned, handled, or manufactured to fit the experiment out of necessity, therefore misrepresenting nature as it truly exists. Instead, it creates a microcosm of nature, fixed enough in time for successful experimentation, but not nature as it exists uninhibited or unobserved. This sounds similar to uncertainty, at the moment of subatomic particles’ exposure to gamma rays, freezing them unnaturally, but observable, once again out of necessity for experimentation.\textsuperscript{17}
We might also describe dramatic literature as an attempt to freeze humanity on stage. Every play is a snapshot, that frozen moment when only a part of the whole flashes before our eyes, never to be seen exactly the same again. Just as the particles are frozen by gamma rays, halted in their motion and never again to be seen in that unique arrangement, the fleeting experience of a theatrical performance is frozen when enacted, then released into oblivion the moment it is over. To expand that thought, we might consider the content of a play as fleeting glimpses of humans as they can be. The playwright and the audience view them briefly in a unique arrangement, the momentary glance at one particular attribute of humanity.

Before exploring *Copenhagen* I wish to briefly discuss two things. The first is to consider the “science play,” what we mean by that, and whether is it an isolated genre. The second is to examine some benchmark science plays from the twentieth century and how each articulates central issues typical to science plays. This way we may fix *Copenhagen* into a spectrum more effectively, and better understand its relative merits and shortcomings while representing the genre.


5 Snow 70.


7 Cargill 94.


9 Rousseau 589.

10 Rousseau 590.


13 George 174.


16 Broderick 81-2.

17 Broderick 82-3.
CHAPTER 2

SCIENCE PLAY AS GENRE?

2.1 THE GENRE OF SCIENCE PLAY

In attempting to explore this chosen collection of plays, I believe that the question of whether the “science play” is a genre unto itself merits addressing. Could these plays, written across national and temporal bounds, be considered members of an exclusive assembly that blurs the boundaries between two disciplines? I imagine most of the playwrights discussed here would deny the intention of writing a play only about science, or one distinguishable from, for instance, a history play. Instead, these playwrights would probably claim that they encountered dramatically viable stories and topics, nothing different from plays about sports, music, or war. Another consideration would be whether these plays are distinct from science fiction. Could not Proof be considered science fiction, or even Copenhagen and Galileo, for their fictitious use of historical characters?

It seems that defining a science play genre is difficult at best. What plays should be included in the canon? Surely Copenhagen, Arcadia, and A Number. The playwrights have filled the dialogue with scientific jargon, characters, and study. Brecht’s Galileo and Dürrenmatt’s The Physicists utilize overt scientific discussion and
well known personalities, so they make clear candidates. But what of Stoppard’s *Hapgood* or Auburn’s *Proof*? The complex mathematics of *Proof* serve primarily as a backdrop for the action, but not part of it. Catherine could be inheriting her father’s talent for soccer, literature, or politics; Auburn’s dialogue never delves into specific mathematical topics. Stoppard has been criticized over *Hapgood* for poorly integrating the science into the story of the play. “Kerner’s [the play’s resident physicist] long-winded physics lessons,” Richard Hornby notes, “seem merely tacked on to the plot.”¹ None of *Hapgood’s* action hinges on Kerner’s speeches; indeed, cutting them would leave us still with a fairly interesting and complete spy story. Do *Proof* and *Hapgood* fit the genre of science play?

Perhaps “science play” is not the best name for these plays. A more useful designation comes from Carl Djerassi in the preface to his play *An Immaculate Misconception*. Djerassi approaches science plays from the unique perspective of a scientist. From his point of view, the divide between the two cultures is a wide one, and he seeks to close it. He employs the term “science-in-fiction” or “science-in-theatre” to describe his goal.² These works are set apart from science fiction, and are defined by plausibly describing the “idiosyncratic behavior of scientists.”³ In other words, science-in-theatre accurately involves itself in the subculture of scientists. I believe this to be a very helpful label, although it requires the presence of a scientist character. Adhering strictly to Djerassi’s guideline would exclude plays like *Inherit the Wind* or *A Number*, which focus on the implications of science rather than the logistics of science itself. Perhaps “science-in-theatre” could be modified to include not only the scientists’ subculture, but the direct effects of that culture’s work on the public.
A further designation connects the form and content of science plays. Often the structure and action of the plays reflect their scientific subject matter. The actors' movement in both *Hapgood* and *Copenhagen* replicates the movement of subatomic particles, progressing in and out of loose patterns. I will reserve discussion of *Copenhagen* for later, but the opening scene of *Hapgood* provides an excellent example. The play begins in the locker room of a municipal pool, where British and Soviet intelligence agents sneak in and out of shower stalls, exchanging or intercepting briefcases. The action, although difficult to understand on the page, quickly begins to represent the hypothesized orbits of subatomic particles. A number of reviewers and even Stoppard himself describe the movement as "choreographed."\(^4\)

Likewise, Stoppard's organization of *Arcadia* has invoked a number of comparisons to the tenets of chaos theory. Susanne Vees-Gulani and Lucy Melbourne separately discuss how the two time periods in the play mirror each other imperfectly like self-similar structures of fractal images: graphs created by reiterating certain algorithms whose attributes reflect each other on different scales, while never precisely coinciding.\(^5\) Likewise, *Arcadia*'s plots set in 1809 and 1993 echo each other closely, even in staging techniques such as couples from both time periods dancing simultaneously, while never corresponding exactly. In addition, Stoppard's other themes of sex, literature, and landscaping serve as strange attractors — phenomena within nonlinear systems that limit its range — which warp the structure of play, notes Vees-Gulani.\(^6\)
William Demastes sees an understanding of chaos theory reflected in the structure and content of many plays – scientific and otherwise – beginning with Henrik Ibsen’s *The Master Builder*, continuing in Samuel Beckett and the Absurdist, and through Tom Stoppard’s corpus, culminating in *Arcadia*. He dwells in particular on Stoppard’s use of the “butterfly effect” of sex that prevents easy understanding of human behavior and history. The butterfly effect of chaos theory describes how tiny actions can have larger, unforeseen consequences, often summarized as the flap of a butterfly’s wings affecting stormy weather across the world. Demastes suggests that the unanticipated human attractions in *Arcadia* make an accurate interpretation of history difficult.

Pertinent to this discussion is Damien Broderick’s brief assertion of the scientific report as a proposed genre. The intention behind the report, he says, is that of a detached voice that theoretically lends itself to effective experiment, namely that the experiment is objective and capable of being repeated with similar results in other laboratories. If every author of science plays intended such an objectivity, grouping them would be easier; however, while some playwrights may intend an attempt at objectivity similar to a scientific report (such as Brecht in *Galileo*), to claim that every playwright aims for an objective voice is problematic at best.

2.2 GOALS OF SCIENCE AND LITERATURE

Much has been said regarding the common goals and methods of science and literature. Although some studies may stretch their boundaries a bit, they do highlight important similarities between the two fields. I believe Broderick describes their
overlapping goals most succinctly, quoting from Joseph Gusfield in saying that they both seek to “construe reality.” Another valuable comparison is K. G. Denbigh’s application of Niels Bohr’s complementarity principle to the relationship of science and literature, saying, “This view has clearly an important bearing on the relationship of science and the arts, which are seen to present aspects of truth applicable to quite different ways of looking at the world.” The tools of science and literature, Denbigh asserts, sometimes differ completely and sometimes overlap, but their ultimate intention to generate understanding remains the same.

Broderick objects, however, and I am inclined to agree, to the distinction that science proceeds from an objective standpoint while art approaches reality subjectively. The problem, Broderick notes, is that language (rhetoric, he says) is never entirely objective or subjective, in either science or literature. Both depend on agreement within the community, yes, but those agreements on language are continuously being revised and reshaped.

2.3 INFLUENCES IN WRITING SCIENCE FOR THE STAGE

One important angle in understanding science plays and their creators is knowing what stimulated writing science for the stage. Sometimes scientific subjects and their philosophical implications fit with a playwright’s existing preoccupations. Mary Doll argues convincingly that Stoppard, before writing *Hapgood* or *Arcadia*, had established a fascination with concepts of uncertainty, disorder, and structure: “If classical theatre, like classical science, depended on stable order, then the study of chaos, like a Stoppard play, depends on dynamic orders.” Likewise, Richard Hornby
notes that the use of mathematics shows up in the first of Stoppard’s plays, as far back as the opening scene of *Rosencrantz and Guildenstern are Dead*, in which the title characters discuss mathematical probability in coin tosses.\textsuperscript{15}

Michael Frayn’s interest in uncertainty and the philosophical implications of modern science stretches back over two decades before *Copenhagen*. His 1974 philosophical treatise *Constructions* makes direct references to Heisenberg and the Indeterminacy Principle. He speaks briefly of the nature of theatrical storytelling that continues independent of the audience, which frustrates and yet draws in its members. “We see a world from which we are absent,” he says, “a world in which the Indeterminacy Principle has been suspended, so that we are able to observe without our presence altering what we observe.”\textsuperscript{16} These lines echo his later preoccupations with the role of the observer evident in *Copenhagen*.

Vees-Gulani notes that many scientific subjects make their way to playwrights through popular literature.\textsuperscript{17} In the case of Tom Stoppard and *Arcadia*, chaos theory came to him primarily through James Gleick’s *Chaos: Making a New Science*, one of the initial bestsellers on chaos theory, although its overall accuracy of representation has been debated. Similarly, *Hapgood* is based almost exclusively on Richard Feynman’s “Lectures on Physics” and Stephen Hawking’s *A Brief History of Time*.\textsuperscript{18} Likewise, David Auburn’s use of mathematicians in *Proof* developed out of his reading of G. H. Hardy’s *A Mathematician’s Apology*.\textsuperscript{19}

Playwrights may also discover their stories through the personalities behind the science. Thomas Powers’ 1993 biography *Heisenberg’s War* sparked Frayn’s interest in Heisenberg’s life and its parallel to his work.\textsuperscript{20} Although he harbored an interest in
Heisenberg and uncertainty, Frayn did not take up Heisenberg’s story until reading Powers’ book. As with Frayn, Peter Parnell’s focuses his play \textit{Q.E.D.} specifically on the eccentricities of physicist Richard Feynman.

When examining these few influences, Oscar Cargill’s earlier warning about latching on to transient theories does seem particularly relevant. He warns of attaching too much value to passing theories, in a sense making a profit by writing about audiences’ current fascinations, and possibly jeopardizing a play’s potential for timelessness. Frayn and Stoppard, at least, became interested in their topics as dramatic material first and foremost through popular works on science, but this may implicate only Stoppard and Frayn. Caryl Churchill, in writing \textit{A Number}, drew more influence from media exposure and actual scientific discussion of human cloning. Initial influence by popular or transient works, however, does not imply the only influence, or necessarily a bad influence. Stoppard, Frayn, and many of the playwrights discussed here are renowned researchers and considered more than capable of accurately rendering scientific fact on stage. Regardless of any scholar’s disdain for “popular” works of science (Hornby, for instance), such works may succeed where scientists fail – by making intricate theories more accessible to a wider public. In addition, Cargill’s argument, aside from assuming that all playwrights write for future generations, is defeated by the fact that nearly every play ever written becomes obsolete with the passage of time, while many plays remain classics despite their use of outdated material.
2.4 IMAGES OF THE SCIENTIST

Roslynn Haynes notes in the introduction to her book *From Faust to Strangelove* that surveys amongst social groups generally reveal an unfavorable image of scientists, based mostly on older, fictional scientists such as Dr. Faustus, Dr. Frankenstein, and Dr. Strangelove.\(^{21}\) So it seems the dramatic portrayal of science does bear relevance to culture, and even has a duty to tell the truth. Scientists themselves treasure a positive self-image, says Haynes, and see themselves as worthy contributors to society. She sees hope in science’s links to literature: “Although literature has most frequently acted as a mirror, reflecting contemporary attitudes towards science and scientists, it has sometimes pointed the way to new insights.”\(^{22}\) The key, she notes, is maintaining an open dialogue between the two.

A number of the plays involved here use historical characters of science, from Werner Heisenberg and Niels Bohr (*Copenhagen*) to Albert Einstein (*The Physicists, Picasso at the Lapin Agile*), Isaac Newton (*The Physicists*), Galileo (*Life of Galileo*), Robert Oppenheimer (*In the Matter of J. Robert Oppenheimer*), and others (*Oxygen*). The use of these characters invites further discussion about the accuracy of their depiction. I will discuss Michael Frayn’s treatment of Heisenberg and Bohr later. However, I must note that in using historical scientists – as with any historical personality – playwrights invoke the stereotypes of those characters, allowing opportunity to comment on the character or flesh out their qualities.

Haynes divides depictions of the scientist into six broad categories. She draws the lines thus: the alchemist, the stupid virtuoso, the Romantic depiction of the unfeeling scientist, the heroic adventurer, the helpless scientist, and the idealist. She
notes that a majority of these designations depict a scientist who is cruel, indifferent, or isolated. Many representations portray him or her as mad, sometimes with a connection to – or desire to connect to – the divine by exercising powers of creation and destruction. Other designations render the scientist as oblivious or helpless.\textsuperscript{23}

The plain fact is that scientists are involved in the culture surrounding them. N. Katherine Hayles, in the introduction to \textit{Chaos and Order}, proposes that this stems from the goal of objectivity in scientific research:

So strong is the ideology of scientific objectivity that practitioners and laymen alike often speak as if scientists were hermetically sealed within the laboratory, isolated from and immune to the thousands of experiences that constitute the fabric of everyday life.\textsuperscript{24}

The drive for objectivity in observation and repeatability in experiment, even if they are never fully achievable, lends itself to the image of an isolated scientist, and only reinforce the negative stereotypes described by Haynes. The efforts of the playwrights discussed here, then, may be seen as attempts to reconnect the scientist with society, or at least the scientist’s image with society.

2.5 TRANSFERRING SCIENTIFIC LANGUAGE TO DIALOGUE

One of the most important methods through which difficult or “isolated” scientific discourse can be made accessible is the spoken language. Its importance, however, brings with it deep concerns on the part of writers and scientists alike. Broderick warns of the inherent difficulties in applying scientific language to everyday situations, at least without making the context clear.\textsuperscript{25} Frayn’s \textit{Copenhagen}, for
instance, could be accused of not fully explaining that quantum mechanics attempts to
describe life at the most minute levels. He most likely understood uncertainty, but may
have failed to specify the context for its application.

Broderick's clearest enunciation of the differences between scientific and
literary language describes his concern not with their mutual use of metaphor, but with
the more stringent agreement within the scientific community on the use of language.
There must be a more clearly delineated agreement regarding the boundaries of
language and its reception within the scientific community, he says, despite ever-
changing definitions.26

Language, he also addresses, is historically contingent. This couples with the
warning from Cargill about latching onto scientific language— or any language, for that
matter— which may quickly outdate itself. The danger, Cargill declares, is creating a
play that hinges too heavily on language whose effect can easily become obscured.
Perhaps Frayn's use of historical characters constitutes an attempt to defeat that
concern; setting the play in the past automatically distances the audience to a certain
degree, and requires the playwright to provide the necessary exposition. How would
Cargill respond, however, to an accusation that Shakespeare's plays use outdated
language? Archaic language rarely prevents Shakespeare from performance. The same
may be said for many playwrights' work; indeed, most playwrights seem most
concerned with making themselves understandable to their contemporary audiences.

Hayles carefully defines the term "chaos" before beginning any discussion, even
mentioning the tendency within the scientific community to stray away from the term.
She cites works such as Gleick's Chaos as causing the term to become thoroughly
“deprofessionalized” by over-using or mis-defining it. Frayn engages the term “uncertainty” in a similar manner, citing its tendency to mislead. “Indeed, the very idea of uncertainty seems to imply the possibility of certainty,” he says. The possibility of certainty defies Heisenberg’s principle; Frayn turns to the awkward “indeterminability” to complete the concept. These minute examples of “chaos” and “uncertainty,” so tightly wrapped in numerous associations, illustrate the point that a playwright must exercise extra care in choosing his or her words.

Demastes provides one final caution regarding the use of scientific images as metaphor. He first praises Stoppard for going beyond using quantum mechanics in Arcadia, because they “can at most be used metaphorically, since it does not directly apply to human dynamics,” but then cautions against poor writing that would inaccurately create metaphors out of scientific images. The classical language of physics, after all, may still be applied macroscopically, and Frayn goes to great lengths to establish his understanding of “uncertainty” as a term constantly misapplied to situations other than quantum mechanics.

2.6 COMMON THEMES AND APPLICATIONS

So what common threads run through these plays? Are there any plot devices or structures common to the group? I want to briefly touch on some similarities between a few representative science plays. Obviously not every play incorporates these elements; the difficulty in designating a science play genre is their unique construction across the board.
Very often these science plays involve a retrospective look across time, usually incorporating a revision or a discovery in the past. That past is frequently performed for the audience, sometimes by the characters trying to interpret it. For instance, *Copenhagen* features three characters re-enacting one event. They step easily in and out of their dual roles as narrators and actors. Similarly, the playwrights divide the action of *Arcadia,* *Oxygen,* and Shelagh Stephenson’s *An Experiment With an Air Pump* into past and present; the present day characters attempt to reconstruct the past.

Authors of science plays also frequently choose to place historical characters in different contexts, and to varying effect. Arguably this was Brecht’s goal in presenting the *Life of Galileo* to modern audiences; the historical displacement would alienate the audience from responding personally. Einstein finds himself displaced in both *The Physicists* (along with Isaac Newton) and *Picasso at the Lapin Agile.* The intent may be merely humorous, or to shed new light on the scientist’s contributions.

Since many plays engage in a past-present dialogue, discussion usually arises around the nature of knowledge. In reconstructing the past, characters in *Copenhagen,* *Hapgood,* *Oxygen,* and *Arcadia* must ask themselves how they know what they know. Oftentimes the relevant scientific theory applies here. Since time acts as a nonlinear system, the characters in *Arcadia* cannot hope to account for all strange attractions in calculating the past. Owing to the indeterminability of the most minute whims of any human being, Heisenberg will never fully understand his motivation in *Copenhagen.* Or, like the results of the complementarity principle in physics, Hapgood’s predetermined biases will only allow her to find the answer she already believed correct, regardless of its true accuracy.
Scientific advance often poses a challenge to existing values, which must respond and adapt to it, offering the playwright some fruitful dramatic conflict. One overt example is the religious opposition Galileo faces in Brecht’s play, as church leaders fear Galileo’s new discoveries may undermine their authority. Jerome Lawrence and Robert E. Lee’s *Inherit the Wind* offers another perfect example, based on the true story of a nation thrown into upheaval by the conflict between traditional beliefs and emerging theories. Finally, Michael Frayn gives Bohr a rousing speech in *Copenhagen*, wherein he summarizes how science has alternately placed humankind both at the center and the outskirts of the universe.

If a playwright draws images and metaphors out of a difficult topic of science, it becomes necessary for him or her to provide additional exposition. One most likely cannot assume that audiences remember their quantum mechanics, thermodynamics, chaotics, and string theory, much less their high school physics class. One final similarity is the need to elucidate the science, or, to borrow from Bohr in *Copenhagen*, the need to explain, “What does it mean, in plain language?” Born out of this need are such complicated and nuanced conversations as Valentine explaining chaos theory to Hannah in *Arcadia*, Kerner explaining quantum physics to Hapgood, the chemists explaining their experiments in *Oxygen*, or Einstein illustrating relativity to Picasso at the Lapin Agile. The difficulty of writing appealing dialogue that illuminates the science surely poses a challenge to even the most renowned playwrights.
2.7 SCIENCE PLAY AS A ‘HANDOFF’

By now I hope some similarities in construction, purpose, and use may show that the plays I have gathered here are more than a random assembly. They have in common the use of “hard” science – mathematical or scientific dialogue and topics that are partly reflected in the structure of the play. These plays serve as excellent examples of playwrights’ using science to further explore multi-faceted human beings. Scientific theories initially used to describe the natural world are brought to bear on people. A study of these plays can yield some clues to how drama can incorporate, explain, and draw meaning from science and what makes it successful (and according to whom?). What do these examples have to say about how we measure and understand the human being?

One central concern is technology – science applied to our lives – and how we appropriate it. How will one group (non-scientists) understand and appreciate the accomplishments of the other (scientists)? It is a valid concern, and C. P. Snow addressed it well. In fact, the two cultures troubled him:

It is dangerous to have two cultures which can’t or don’t communicate. In a time when science is determining much of our destiny, that is, whether we live or die, it is dangerous in the most practical terms. Scientists can give bad advice and decision-makers can’t know whether it is good or bad.\(^{33}\)

Snow wrote at a time when nuclear weapons posed the threat of total destruction to humankind. But what to say of debate over human cloning and genetic research? Space exploration? Computer technology? A careful understanding must be built between those who create and those who use.
Lee Riedinger, Deputy Director of Oak Ridge National Labs, noted at a recent symposium on *Copenhagen* that the difficulty is “the handoff.” Scientists, he said, tend to be idealistic, or do not have a head for political thinking, so they do not always foresee the complications of their discoveries. The hardest part of the job for a scientist, said Riedinger, is turning over his or her work to someone who did not work toward its development, someone who may not have the same sense of responsibility.\(^\text{34}\)

From Riedinger’s comment I wish to take my definition and model for the science plays discussed here. Although defining the science play genre may be a fruitless exercise, and asking “What makes a good science play?” may be no different than asking “What makes a good play?”, I believe that an adequate model can be found in saying that a play itself is a sort of handoff. This handoff takes place on a two-fold basis. First, the play is a handoff because the scientific topic arrives in the hands of a playwright, someone who most likely does not have firsthand knowledge of it. Scientists, then, rely on the playwright to handle their field responsibly, to properly represent and teach the subject, and to further explicate life with the complementary fields – to summon Denbigh – of science and literature. The play is secondly a handoff in that the playwright gives the play to his or her audience. How will it be received? Will it be used responsibly? What other factors might affect it such as political considerations and personal biases?

And here we encounter the greatest difficulty, the most substantial source of contention amongst scientists, historians, scholars, and dramatists. How will they handle each others’ respective fields? Can a scientist properly understand literary theory? Can a playwright represent history accurately? The answer seems to be, in all cases, a
resounding yes. In light of this, I wish to examine a few plays from the twentieth
century that have contributed most significantly to the growing relationship of science
and drama.


3 Djerassi ix.


6 Vees-Gulani 417.


8 Demastes 253.


13 Broderick 94.


15 Hornby 279.


17 Vees-Gulani 411-412.


22 Haynes 5.

23 Haynes 3.


25 Broderick 102.

26 Broderick 101-2.

27 Hayles 2.

28 Frayn, *Copenhagen* 99.

29 Frayn, *Copenhagen* 100.

30 Demastes 253.


32 Frayn, *Copenhagen* 65.

33 Snow 98.

CHAPTER 3

A BRIEF REVIEW OF BENCHMARK SCIENCE PLAYS

3.1 INTRODUCTION

In this chapter I will briefly examine a few plays from the twentieth century exemplifying effective use of science in playwriting. This selection originates in three countries – Germany, Britain, and the United States – although not to the purposeful exclusion of science in playwriting around the world. Rather, I have chosen these plays, excepting A Number, because of the immense scholarship that has sprung up around them. I have included A Number for its recent writing by a prominent playwright and because it may point the way toward the future of the science play.

I will discuss each play’s subject, the playwright’s relationship to the play, what theories are used, how they are taught and applied, and the specific contributions to science and drama the play has made.

3.2 BRECHT’S LIFE OF GALILEO: THE SCIENTIST’S RESPONSIBILITY

I wish to begin with one of the quintessential science plays of the twentieth century. More symposiums and conferences have sprung up around this play than any other (partly because it is the oldest play discussed here). Eric Bentley, in his
introduction to *Life of Galileo*, quickly points out that Brecht actually misunderstood Galileo’s science, mistaking his new cosmology as forcing humankind from its central status and onto the periphery. Instead, Bentley points out, to be on the periphery was prestigious, for that is where God lived. Galileo’s major contribution made physics more mathematical, relying more on calculation than directly observable evidence. The sun, after all, appeared to circle around the earth.

At the beginning of the play we find a poor Galileo working in Padua, taking on students at the behest of his housekeeper. Ludovico, his first new student, informs him of a new invention from Holland: the telescope. Quickly realizing how it works, Galileo constructs his own and sells it to officials of the Grand Arsenal of Venice, who hail his genius and compensate him richly.

The great scientist, however, has been up to more than simply marketing his telescope. Turning it to the heavens, he quickly makes discoveries about the solar system, in particular discovering that the Moon has a mountainous landscape similar to Earth and that Jupiter seems to have smaller moons revolving around it. The latter discovery implies that the stars are not held in their crystal spheres, revolving perfectly around the earth as believed since Aristotle, but that the earth may be a subsidiary planet revolving around a “second rate star” like the Sun.¹ This discovery challenges the Biblical passage of the Sun being commanded to stand still.

Later, Galileo has been made Court Mathematician in Florence to the young Prince Cosimo de’ Medici. Sharing his discoveries with the Prince and the court scholars, Galileo causes a stir. He makes himself a laughing stock to religious and political leaders; however, Father Christopher Clavius’s support of his discoveries
causes a deeper stir, and Galileo finds himself in heated arguments with the Cardinal Bellerini. The deep implications of his discoveries are brought to the forefront by Galileo’s assistant, the Little Monk, who asks what his parents, poor peasant laborers, are to think, knowing that their lives are not the literal center of God’s creation, but banished to the outskirts on an insignificant planet. Galileo retorts that advances in knowledge could ease his parents’ struggles. Meanwhile, in the streets a ballad singer sings about the repercussions of Galileo’s findings to the population.

Galileo pushes ahead, even at the expense of his daughter’s marriage, and finds himself before the Cardinal Inquisitor and Cardinal Barberini, now Pope Urban VIII. Despite his students’ hopes, Galileo caves under the Inquisitor’s pressures and goes under house arrest for the next eight years, promising to relinquish all research on the solar system. The final scene shows the astronomer, his sight failing him and under the care of his daughter Virginia, in his house apparently conducting innocuous experiments. A visit from Andrea, who informs his old master of the repercussions of his recantation, prompts Galileo to hand him the completed manuscript of his Discorsi, the findings of his banned research. Andrea promises to smuggle it out of the country for publication. The playwright reveals that Galileo’s eyesight has deteriorated because he has been observing the heavens at night. Although Galileo confesses cowardice for his reason to recant eight years prior, the scene ends hopefully with his question to Virginia, “How is the sky tonight?” to which she replies, “Bright.”

Although Brecht apparently misunderstood Galileo’s story, he seemed to have a firm grasp on contemporary science, and even referenced it in his writings. Allen E. Hye’s essay “Brecht and Atomic Physics” claims, using his plays and diaries, that
Brecht comprehended modern scientific theories like relativity and uncertainty and even reconciled them with Marxist teachings. He demonstrates how Brecht used uncertainty as a metaphor for his work and how he hoped to understand the behavior of the individual using it. Indeed, says Hye, Brecht viewed human beings like subatomic particles, known only in probability and as the subject of experiments, whereby the individual is placed in proximity to different forces and his or her reaction studied. Hye even proposes that Brecht’s familiarity with uncertainty and the scientific method led him to create the artistic parallel of epic theatre. Some of these claims may be too substantial, but Brecht certainly had a clear understanding of modern science.

*Galileo* is the first play discussed here that takes a historical figure and uses his or her story for its own purposes. Brecht manipulated Galileo’s character, life, and science to fit his ideas of twentieth century science. First having written the play in 1938, he revised it in 1947. The motivation behind his revision seems primarily the deployment of the first atomic bombs, whereupon his focus shifted from the scientist’s freedom to experiment to the responsibility a scientist has to the greater community of scientists and to humanity at large. So Brecht further revised history once his modern perspective had changed. Bentley discusses the purposes of historical drama, concluding that Brecht and other dramatists may have rearranged history because, “The truth offended their sense of truth, and out of the less dramatic they made the more dramatic.” In a sense, Brecht adjusted the truth to more effectively demonstrate his ideas.
One element of these science plays I wish to examine is how the playwright chooses to teach or apply the chosen scientific theories. Brecht uses the teacher-student relationship to teach the basic astronomy of the play. Young Andrea, son of Galileo’s housekeeper, follows him around his study asking questions, giving both Galileo and his author the chance to demonstrate his new discoveries. He creates a small model of the solar system using objects in his room, placing a washstand in the center as the sun, and then revolving Andrea in a chair around it. He thus explains to Andrea how the washstand seems to move, even though it remains fixed while he moves. Brecht uses the student-teacher model frequently throughout the play. The final scene involves Andrea teaching a young boy, who believes a neighbor woman is a witch based on her shadow cast on the wall. Andrea instructs him to extend his observations and look closer, whereupon the boy learns that she is an old woman making soup, not a witch at a cauldron. Though Brecht does not explicitly apply the scientific theories as a metaphor, he uses Galileo’s physics and astronomy as the basis for a discussion on the nature of new-found knowledge, cautioning specifically against believing only what one sees.

Like Lawrence and Lee’s Inherit the Wind, Galileo contributes specifically to the ongoing dialogue between scientific theory and institutions such as the church. Both plays derive their conflict from the friction usually existing between science and religion. In Galileo, Brecht demonstrates a complete contrast between the scientist and theologian; the former relies on the evidence of his senses, while the latter relies on reasoning and imagination. Brecht polarizes the issue to such a degree that his protagonist cries, “I’m not a theologian; I’m a mathematician!” The conflict reaches the extent of Galileo’s inquisition and recantation when shown torture devices. One
might even critique Brecht for not giving the church a chance: Cardinal Barberini and other leaders are shown to be singularly obtuse, denying Galileo any opportunity to undermine their authority.

Brecht also briefly touches on technology, the application of science. Early in the play, when Galileo presents his telescope to the city leaders of Venice, the Curator of the museum makes a speech, in which he praises the various uses of the telescope. In this short speech, he appeals to other leaders present, noting, to louder and louder applause, that the telescope represents greater advances first in Venetian culture, then in manufacturing, then in military combat. Galileo seems to have no qualms selling the invention as his own, even though he stole the idea from Holland, and appears displeased when someone reveals its true origins.

*Galileo* contributes primarily to discussion about the responsibility of the scientist to society. The duty, Brecht says, is to communicate one’s findings, no matter how scandalous or defiant of the strictest tyranny. “As much of the truth gets through,” cries Galileo, “as we push through.” However, Brecht condemns Galileo for his cowardice (untrue to the historical man), even considering his actions treacherous, saying explicitly,

Galileo’s crime can be regarded as the original sin of modern physical science. ... The atom bomb, both as a technical and as a social phenomenon, is the classical end product of his contribution to science and his failure to society.  

He makes this obvious in the final lines of the play:

May you now guard science’ light,  
Kindle it and use it right,  
Lest it be a flame to fall  
Downward to consume us all.
Galileo’s weak point, says Brecht, is that he sets out on a quest to change the world, then relents. He neglects the responsibility he owes to the world, despite opposition from religious or civic leaders, to share his discoveries, caving in to Cardinal Barberini’s quoting of Proverbs, “A prudent man concealeth knowledge.”\textsuperscript{12} We learn towards the end of the play that, because of Galileo’s recantation, many of his colleagues abandoned their work: Descartes gives up astronomy in Paris, Andrea must travel to Holland to find employment, his assistant Federzoni must go back to grinding lenses for a living, and the Little Monk forsakes research to live in a monastery. The point is clearly made – Galileo’s abandonment of his work has served as an example to many other great minds.

However, Brecht offers us words of hope. Galileo, having finished his Discorsi, passes it on to Andrea, who is headed out of the country. In his excitement, Andrea praises Galileo for his heroism, whereupon his teacher issues him a stern warning about the implications of new discoveries: “New machines may simply suggest new drudgeries.”\textsuperscript{13} Despite these warnings, however, Brecht leaves us with the image of Andrea attempting to pass on the new knowledge.

3.3 DÜRRENMATT’S THE PHYSICISTS: IMPLICATIONS OF DISCOVERY

Friedrich Dürrenmatt’s The Physicists is often associated with Brecht’s Life of Galileo. They both are written in Germany, both are post-World War II plays, and both deal with the responsibilities of the scientist. While Brecht concludes with an optimistic vision of science serving society, however, Dürrenmatt ends with a pessimistic view of society always misusing technology.\textsuperscript{14}
In his opening stage directions, Dürrenmatt explains his wish to adhere to the
unities of time, space, and action, since “the action takes place among madmen and
therefore requires a classical framework to keep it in shape.”\textsuperscript{15} The setting is the
dilapidated Les Cerisiers, a villa turned asylum. This particular wing of the asylum
houses three physicists: one thinking he is Sir Isaac Newton, one believing himself to be
Albert Einstein, and a third named Johann Wilhelm Mobius. A nurse at Les Cerisiers
has just been strangled by Einstein, and the police are investigating. Through the
Inspector’s opening conversation with Nurse Boll, we learn that Newton murdered his
nurse three months prior.

While waiting for the head doctor, Fraulein Doktor Mathilde von Zahnd, the
exasperated Inspector meets Newton, who further confuses the Inspector by insisting
that he is actually Albert Einstein and only pretending to be Newton. The Doktor finally
emerges and speaks with the Inspector, who recommends to her that male attendants
replace the female nurses at Les Cerisiers. The Doktor agrees, ushers the Inspector out
the door, then brings in Mobius’ family. His wife, who supported him in his madness,
has remarried to a missionary who will take her and her three boys to the Mariannas.
When the boys, meeting their father for the first time, play a recorder trio for him,
Mobius feigns a bout of lunacy to drive them permanently away. He confesses this to
Nurse Monika, with whom he has had a secret relationship. In speaking with Monika,
he learns that she has come to believe his visions of King Solomon, who revealed to
Mobius the Principle of Universal Discovery. When Monika expresses her desire to
take Mobius away from the villa and marry him, he strangles her with a curtain rope.
The second act begins with another visit from the Inspector, who now holds the upper hand over the Doktor. The newly stationed male attendants – all former boxing champions – arrange dinner for the three physicists. Over dinner we learn Newton’s and Einstein’s true identities; they are, in fact, they are rival foreign intelligence agents vying for Mobius and his discoveries. Both had murdered their nurses because the women drew too close to the truth. Unfortunately, the murders have prompted a lockdown in the institution, and the male attendants, reinforced by new steel bars over the windows, turn the villa into a prison. Despite Newton’s and Einstein’s offers to help Mobius escape and become famous, he convinces them that, for the benefit of humankind, they must remain forever at Les Cerisiers and keep his discoveries hidden. Once they agree, however, the Fraulein Doktor enters and reveals to them her madness: she has come to believe in King Solomon and seeks to depose Mobius. Over the past years, she has been photocopying Mobius’ manuscripts. Now, thanks to the nurses’ murders, she can safely lock up the three men under the guise of insanity, while she exploits Mobius’s findings. She tells them that she has already built up industries using her inherited wealth, and prepares now to take over the world. The three men, denied communication with the outside world, resign themselves to their roles as mad physicists.

Dürrenmatt follows up The Physicists with twenty-one points to the play. There he articulates his preoccupation with the paradox of the scientist’s position in society: the simultaneous need to do something about his discoveries and yet do nothing about them. According to Karl Weimar, Dürrenmatt translates the classic structure of tragedy
into the “tragicomedy of the modern paradox,” even comparing Mobius’ dilemma to that of Oedipus.\textsuperscript{16} This preoccupation with paradox, Dürrenmatt implies, leads him to a play about physicists, whose field of study incorporates paradox on every level.\textsuperscript{17}

Dürrenmatt does not incorporate any specific theories of physics in the play, but chooses instead to create artificial theories that Mobius has supposedly discovered, named such things as “the problem of gravitation,” the “Unitary Theory of Elementary Particles,” and the “Principle of Universal Discovery.”\textsuperscript{18} These theories become information to barter, scientific advances of great value to various governments. In his twenty-one points, Dürrenmatt declares his lack of concern with the specifics of physics: “[Drama] cannot have as its goal the content of physics, but its effect. The content of physics is the concern of physicists, its effect the concern of all men.”\textsuperscript{19} So \textit{The Physicists} does not contain any moments of teaching particular theories to someone, but instead engages the dialogue exploring the effects of science.

While \textit{Galileo} focuses on the scientist’s responsibility to communicate his or her findings, \textit{The Physicists} specifically addresses the dangers of mishandling discovery. Mobius realizes the gravity of his findings:

\begin{quote}
MOBIUS. The result is – devastating. New and inconceivable forces would be unleashed, making possible a technical advance that would transcend the wildest flights of fantasy if my findings were to fall into the hands of mankind.
EINSTEIN. And that can scarcely be avoided.
NEWTON. The only question is: who’s going to get at them first?\textsuperscript{20}
\end{quote}

Mobius fears the exposure of his innovations. In lieu of joining the academy or industry, where he would be forced to divulge them, he feigned madness and entered an asylum. Einstein and Newton, upon revealing their identities to Mobius, present him with two
different options. Newton argues for the freedom of the scientist absolved of moral considerations, but Mobius observes that the scientists would be enslaved by the defense of their country. Einstein espouses the physicist's active engagement with the politics of science, dictating who receives discoveries and who does not. Mobius counters that even the brightest physicist will be swept away in the power of politics and grow subservient to a larger system.²¹

All of their plans spiral out of control, however, when the Fraulein Doktor reveals her strategy. She feels that King Solomon appeared to her because Mobius had chosen to hide his findings. Mobius considered himself dangerous because he believed in miracles, and "in the realm of science there is nothing more repugnant than a miracle," he tells Nurse Monika.²² He himself feels that sharing the revelations of King Solomon was a mistake; for that reason, he strangled Monika. However, the physicists' delay has allowed their work to fall into the wrong hands and, unfortunately, "What was once thought can never be unthought."²³

Mobius' final speech, wherein he calls himself King Solomon, offers an interesting metaphor. King Solomon, he says, was once "rich, wise, and God-fearing;" however, his unparalleled wisdom "destroyed the fear of God, and when I no longer feared God my wisdom destroyed my wealth."²⁴ Like Solomon, Mobius' wisdom subdued a proper respect for power and responsibility, the consequences of which have ruined him.

Dürrenmatt also contributes in part to the image of the mad scientist. The three physicists in the play most likely correspond to Haynes' categorization of the romantic image of the unfeeling scientist. These three men are the feeling scientists who need to
control their emotions, murder their nurses, and thus appear heartless. Mobius’ concern with the fate of humanity causes him to take steps to preserve it, resigning himself to spending his life in a sanatorium.

3.4 STOPPARD’S *ARCADIA*: THE ORDER OF CHAOS

Alongside *Copenhagen*, one of the most influential science plays in recent years is Tom Stoppard’s *Arcadia*, a complex weaving of chaos theory, literature, sex, and landscaping. Set in 1809 and 1993 in the solarium of Sidley Park, a fictitious English country manor, *Arcadia* pairs two sets of characters, the present one attempting to decipher the story of the past one.

All of these blend rather seamlessly, in true Stoppardian fashion, into the story of young Thomasina Coverly and her tutor Septimus Hodge, and their flourishing relationship amongst the complex unions of those in the house. The perceptive Thomasina, beginning with her tutor’s lessons and drawing examples from around her, first theorizes what later became the second law of thermodynamics and chaos theory. The terrain around her family’s estate is being reshaped by landscaper Mr. Noakes into the Gothic style, and Thomasina recognizes in it the true form of nature, more complex than the symmetry of Euclidian geometry.

In the same space, Stoppard also shows us the modern day historian Hannah Jarvis, whose interest in Sidley Park’s horticultural past leads her to the figure of a hermit supposedly lodged in Mr. Noakes’ landscape. Disrupting Hannah’s work is the obnoxious Bernard Nightingale, a Byron scholar desperately seeking a connection between his subject and Sidley Park. We come to learn that Septimus was a friend of
Byron, and the consequences of their various sexual exploits at the house mislead
Bernard into believing that Byron shot and killed the mediocre poet husband of one of
his flings.

While Bernard pursues his mistaken hypothesis, Hannah and Valentine, a
descendent of the Coverlies, piece together Thomasina’s past, realizing in the process
that she first envisioned heat loss and entropy. Thomasina’s early death and her
incomplete ideas, we discover, drive Septimus insane. He later becomes the hermit
amongst Mr. Noakes’ romantic landscape, madly attempting to complete Thomasina’s
theorem.

Arcadia contains many parallels and ironies between the two time periods.
Towards the end of the play, Stoppard doubles the action of the two generations against
each other, so we see actions such as Valentine and Septimus examining the same
diagram simultaneously. The two scenes mirror each other imperfectly like pieces of the
fractals created by chaos theory’s mathematics. Lucy Melbourne, in her article “Plotting
the Apple of Knowledge,” describes how the structure of Arcadia represents an iterated
algorithm. This culminates in the play’s final moments, when Septimus and Thomasina
waltz alongside Hannah and Gus, placing the two times in parallel, the present repeating
the past and creating a pattern in the chaos of time.

As I have discussed earlier, Stoppard seems regularly preoccupied with
ambiguity and the difficulty of knowledge. Nearly every book or article on his work
acknowledges this fixation immediately. Richard Andretta describes Stoppard’s
overriding theme as “the elusive nature of reality and the impossibility of reaching final

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conclusions about it.” Mary Doll’s essay “Stoppard’s Theatre of Unknowing” firmly establishes this curiosity of Stoppard, so *Arcadia* and the plays following it proceed logically out of Stoppard’s corpus.

Stoppard’s penchant for science and its applications in representing the ambiguity of life have previously surfaced most noticeably in *Hapgood*. I have declined to discuss *Hapgood* at length in deference to the arguably better-quality *Copenhagen*, however, it lays the groundwork for *Arcadia*’s contribution to the discourse of science and literature. *Hapgood* focuses on the world of espionage; British, American, and Soviet spies vie for scientific secrets, all involving Joseph Kerner, a double – possibly triple – agent for the British. The plot entails some ambiguous motivations, a few sets of authentic and forged twins, and pairs of briefcases being exchanged, interspersed with lectures on quantum physics. During these scientific musings, Stoppard creates effective, albeit blatant, metaphors between subatomic particles’ inscrutable wanderings and the allegiances of spies, between particles’ ability to exist in two places simultaneously and secret agents’ use of duplicity to fool the enemy. Regardless of its quality as a play, *Hapgood* still demonstrates an attempt at integration of scientific theory and playwriting.

The central scene to *Arcadia* is Valentine’s explanation of chaos theory to Hannah. Stoppard located it as the fourth of seven scenes, making it the literal core of the play. He explains various facets of chaos theory all throughout the play, but this particular scene summarizes chaos theory and how the characters encounter it. He does
this in one of the simplest ways possible: by placing someone who knows next to someone who wants to know. Hannah, almost as spokesperson for the audience, elicits Valentine’s explanations.

Stoppard applies chaos theory most notably to the act of historiography. Bernard and Hannah race to reconstruct Lord Byron’s involvement with Sidley Park, although only Hannah seems to understand the irreversibility of the nonlinear system of time. One must rely on intuition, Bernard says to her, “Because time is reversed. Tock, tick goes the universe and then recovers itself, but it was enough, you were in there and you bloody know.”26 The historian can make time run backwards, Bernard claims, essentially placing the adequately prepared scholar in the past. Contrast his remark with Thomasina’s observation nearly two hundred years earlier:

When you stir your rice pudding, Septimus, the spoonful of jam spreads itself round making red trails like the picture of a meteor in my astronomical atlas. But if you stir backward, the jam will not come together again. Indeed, the pudding does not notice and continues to turn pink just as before.27

Thomasina demonstrates the irreversibility of systems such as the march of time or the stirring of jam into pudding. And why cannot one turn back time? Chloe later provides an interesting articulation of chaos theory’s sensitive dependence on initial conditions and the butterfly effect – phenomena that unpredictably affect the movement of a nonlinear system. The problem, she says, is sex:

CHLOE. The universe is deterministic all right, just like Newton said, I mean it’s trying to be, but the only thing going wrong is people fancying people who aren’t supposed to be in that part of the plan.

VALENTINE. Ah. The attraction that Newton left out. All the way back to the apple in the garden.26

44
Chloe’s example applies directly to *Arcadia*, as the unknown, tangled loves and jealousies in 1809 between Septimus, Lady Croom, Mr. and Mrs. Chater, and Lord Byron, make deciphering the past impossible to the modern day historians.

Stoppard seems at his best when demonstrating the public’s misplaced view of chaos. The term “chaos” typically implies complete randomness and disorder, similar to any attempt to explain the full plot of *Arcadia*. Two time periods, numerous characters, discussions of chaos theory, math, literature, landscaping, art, and sex from the point of view of 1809, 1812, and 1993 seems like an impossibly complicated pile of ideas and situations. But upon closer examination, one can see the order amongst the complexity, one can “pick [the tune] out of the noise,” as Valentine says. Stoppard’s use of such “strange attractors” as sex, literature, and the garden imposes a pattern on the play, thus making it effective in communicating a compelling story and explaining chaos theory through its form and content.

3.5 AUBURN’S *PROOF*: PERSONALITIES AND THE PROOF

David Auburn’s 2001 drama tells the story of a young woman living in Chicago and caring for her aging father, Robert, a brilliant mathematician from the University of Chicago. On the eve of her twenty-fifth birthday, Catherine sits on the porch with her father, discussing her sluggish lifestyle and the possibilities of her future. Her father, we learn, has been in deteriorating mental and physical health and Catherine has remained in Chicago as his caretaker, while her sister Claire moved to New York. As Catherine questions whether she has inherited her father’s mental instability, she realizes that he has passed away and she is imagining the conversation. Visiting the house is Hal, a
young math professor and former student of Robert’s studying his extant notebooks. Suspicious of Hal, Catherine accuses him of attempting to steal her father’s notebooks for his own gain; she proves to be correct when a notebook later falls out of his jacket, although he claims he meant it as a birthday gift since the journal includes a passage about Catherine.

The following scene finds Catherine the next morning with her sister Claire, who has flown in for the funeral. Claire expresses her concern for Catherine’s condition and offers a place for her in New York, which she rejects. Later, during an after-funeral party, Hal’s band of math geeks plays and Catherine sits again out on the porch. She and Hal discuss mathematics and eventually find themselves romantically entangled. The following morning, Catherine gives Hal the key to a drawer in her father’s desk. When he exits, Claire enters, and the two sisters begin arguing about the care of their father and the house. Claire reveals her plans to sell the house despite Catherine’s desire to stay. At the height of their exchange, Hal stumbles onto the porch with a notebook, astonished at the important proof within it. When Claire and Hal debate who gets the credit for its discovery, Catherine quietly reveals that she wrote it.

The second half of the play jumps back four years to the day Hal and Catherine met. Catherine has just told her father that she will attend Northwestern University in the fall. Hal visits to drop off a draft of his dissertation to Robert, who has been ailing but is in remission. As the three characters banter back and forth, Robert realizes it is Catherine’s birthday and offers to take her and Hal out to dinner. Hal declines, although not before sharing a brief glance with Catherine. As the younger two leave, Robert opens his notebook and begins writing the entry later to be discovered by Hal.
The second scene picks up where the first act left off, immediately after Catherine's revelation about her work. Claire and Hal find believing her difficult. Despite Catherine's hope that Hal would see the truth, he hedges around the issue and agrees with Claire, causing Catherine to withdraw and even attempt to destroy the notebook. The next morning Hal returns to analyze the notebook, whereupon Claire informs him of her plans to move Catherine to New York.

The play then jumps back a few years, where Catherine, attending classes at Northwestern, has rushed home because her phone calls to the house have gone unanswered. She finds Robert on the porch, freezing but excited. He explains to her that he is mentally recovering and feels motivated again to exert himself. He eagerly shares his work with her, but upon reading the incoherent ramblings she realizes that his mental condition has deteriorated.

The final scene, back in the present, shows Catherine and Claire preparing to leave for New York. Hal catches Catherine before she leaves and confesses that he has studied the notebook and now believes it to be her work. In the final moments they establish a connection, and she sits down to try and explain the proof to him.

Auburn admits having been led to *Proof* not through the mathematics but through the joining of two storylines with which he had been toying. In fact, he has expressed surprise over his work being likened to plays like *Arcadia* and *Copenhagen*. “It seems that it’s unusual enough to have characters in a play who are scientists,” he said, “that people think this is some sort of rich intellectual statement.”31 Instead, he sees the play as a dramatic story incorporating the rich subculture of mathematic scholars.
Proof centers around mathematics; both Catherine’s and Robert’s research focus is prime numbers; Hal refers to Robert’s contributions in the fields of game theory, algebraic geometry, and nonlinear operator theory.\(^{32}\) Catherine also relates the history of prime numbers, specifically the contributions in the late 1700’s by Sophie Germain, known for Germain Primes, which state that doubling any prime number and adding one leads to another prime number.

Contrasting the firm mathematical proofs is that which cannot be proved: intangibles such as trust, love, and faith, for example Catherine’s desire for Hal to believe that the notebook is hers, despite contrary evidence:

CATHERINE. It doesn’t prove anything.
HAL. Okay, what would?
CATHERINE. Nothing. You should have trusted me.\(^{33}\)

His recognition of her work bears relevance to her. Claire, on the other hand, wavers because of similar handwriting and the thought that Catherine could not understand the mathematics. Similarly, Catherine trusts in the completeness of her proof, despite the fragile footing that gets her there. “I know… it works…,” she says, “But all I can see are the compromises, the approximations, places where it’s stitched together. It’s lumpy. Dad’s stuff was way more elegant.”\(^{34}\) In the end, Hal believes in her proof, regardless of its inelegance, and encourages her with, “Give it a shot? Maybe you’ll discover something elegant.”\(^{35}\)

Keeping the focus off the logistics of the science, Auburn contributes to the science play in his treatment of the personalities behind the work. He addresses the stereotypes of mathematicians and scientists as socially ignorant. Hal speaks of his band of math geeks, who perform such songs as “i” – meaning “imaginary number” – in
which they stand silently for three minutes. In contrast to the math geek image, Hal describes mathematicians’ behavior, citing their conduct at conferences, where he claims they engage in rampant substance abuse and sexual experimentation. 36 Claire, during the funeral party, is unfortunately abandoned by her friends to the theoretical physicists, who drink her under the table and then some. 37

Auburn also makes reference to the age of mathematicians, and how it plays a factor in experimentation and research. At Catherine’s age, her father had already made his biggest contributions to the field, and Hal wonders whether Catherine feels any pressure because of it. He also mentions older mathematicians taking drugs because they believe they need it to keep up with younger men:

HAL. They think math’s a young man’s game. Speed keeps them racing, makes them feel sharp. There’s this fear that your creativity peaks around twenty-three and it’s all downhill from there. Once you hit fifty it’s over, you might as well teach high school. 38

This places both him and Catherine in interesting positions. Catherine has just turned twenty-five and produced significant contributions to the field; perhaps she has already peaked in her career and has nothing to look forward to but her father’s mental instability. Hal, three years older than Catherine, has yet to produce notable work. This is obviously a sore point, as Catherine uses it cruelly against him during a heated argument.

The concern with age calls to mind the role of fame and recognition in the scientist’s life. This theme surfaces in many plays, *Arcadia* (who discovered chaos theory) and *Oxygen* (who discovered the element) to name a few. The draw to an isolated scientist, exploring what only a few can understand, receiving popular
recognition for his or her contributions, is clear, and the power of that draw makes understandable the desire to be first. This power is so strong that Catherine reluctantly tells Claire and Hal about her proof. Chris Smith, in an interview with Auburn, suggests that Catherine fears greatness more so than madness or marginalization, although she defends herself against all three.  

*Proof* explores the oft-questioned thin line between genius and madness by placing Catherine near that line. At her age, her father contributed his greatest work and then descended into dementia. Catherine has done the first, and now wonders whether she teeters at the edge. Her sister Claire seems to think so, having scouted possible doctors for her in New York. Auburn also suggests the possibility of Catherine’s volatility in that the first scene, between herself and her father, is an illusion. 

Finally, Auburn addresses the important issue of gender in science and mathematics. Catherine, a twenty-five-year-old woman, faces considerable challenges in her profession. As a parallel to her situation, Auburn draws upon the story of Sophie Germain, a French woman who corresponded with German mathematician Karl Friedrich Gauss over 200 years ago. Fearing that Gauss would ignore her work due to her gender, Germain adopted the pseudonym Antoine-August Le Blanc. Gauss did discover her true identity after five years, at which point he wrote to her,

A taste for the abstract sciences in general and above all the mysteries of numbers is excessively rare, but when a person of the sex which, according to our customs and prejudices, must encounter infinitely more difficulties than men to familiarize herself with these thorny researches, succeeds nevertheless is penetrating the most obscure parts of them, then without a doubt she must have the noblest courage, quite extraordinary talents, and superior genius.
Catherine recites this passage to Hal from memory, demonstrating a profound awareness of her situation. Germain learned the mathematics during the French Revolution, when the Terror forced her to stay indoors. Similarly, Catherine, remaining behind to care for her father, lived in his presence and with his mathematics, allowing her time to integrate the math despite dropping out of school.

3.6 CHURCHILL’S *A NUMBER*: IDENTITY AND NATURE/NURTURE

Caryl Churchill’s 2002 play has the distinction amongst this collection as being the most recently written, and therefore the least written about. Science plays an off-stage, ominous role in *A Number*. Salter, a man in his 60’s, meets with three of his sons, one of whom is his original son, the others cloned from his genetic material. Salter first meets with Bernard Two, his thirty-five-year-old son who he created as a replacement of his first son. Salter had explained to him that his mother and the original Bernard died in a car crash, and that Salter, in his grief, wanted his exact, “perfect” son back, and so had him cloned.41 This Bernard (denoted B2) has just discovered that not only is he a clone, but that the scientists who created him stole his genetic material and created an unknown number of him. He is kind to his father, though obviously disturbed at the prospect, and desirous to meet one of his brothers.

Salter then meets with the original Bernard (B1), who is mentally instable and angry at his father, for Salter had abandoned him in an institution two years after his mother died. This Bernard recalls, as a child, calling out for his father, who never came. He could never tell, he confesses, whether Salter could not hear him, or whether he heard but chose to ignore his son.
Salter meets Bernard Two again, who has come away quite agitated from meeting Bernard One. He noticed immediately the strong differences between himself and his brother, despite identical genetics, and can only conclude that their upbringing was the determining factor. This causes him to blame his father for the mistake, for essentially abandoning Bernard One in an attempt to start over with the second. Bernard Two draws from his father the truth regarding his mother’s death who, in depression, threw herself in front of a train. Fearing his brother, Bernard Two decides to go into hiding.

Bernard One, however, follows his clone to his hotel and murders him, then confesses it to his father, who reacts with more curiosity than fear. We later learn that Bernard One has killed himself. Salter then meets another one of his sons, Michael Black, who seems to irritate his father with his optimism and inability to understand his father’s questions. Salter wants to know specific details about Black’s personality, as if testing to see how he differs from his brothers, but Black cannot resist sharing his various fascinations in life. The play ends with the contrast of Salter’s bitter apathy and Black’s joking optimism.

Due to its recent writing, very little scholarship has been published about A Number, and little has been documented from the playwright herself. I include this play because it perhaps shows the future of effective science plays, which may continue to engage complex issues on a human level. Churchill brings to the table the ongoing discussion of genetics and cloning, rendering its effects in very human terms. Like Galileo and The Physicists, A Number deals less with the specifics of science and technology, and more with their implications on a human level.
A Number treats the dehumanizing effects of science. Every version of Salter’s son questions his individuality in the face of several existing versions of himself. “They’ve damaged your uniqueness, weakened your identity,” Salter tells Bernard Two, who briefly despairs and muses, “I’m just a copy. I’m not the real one.”

Despite all concerns about individuality, the characters still attempt weak estimations of a single life. Salter and Bernard Two discuss mounting a lawsuit against the hospital and discover the need to place a monetary value on human life; they finally decide on half a million pounds per person.

The situation invokes varieties of curiosity from the characters. Salter questions each son about his individual likes, dislikes, habits, and ailments. The first Bernard reacts with anger. On the contrary, both the second Bernard and Michael Black are fascinated. “It’s an adventure isn’t it and you’re part of science,” Bernard Two says, “I wouldn’t be frightened to meet any number.”

Churchill questions whether this type of cloning encourages a view of life as disposable. Salter apparently felt that he raised his original son poorly, so he had the boy cloned and gave him away. “They take this painless scrape this specky little cells of me,” the original Bernard cries, “and kept that and you threw the rest of me away.”

The concept of “do-overs” makes its way into the realm of paternity, and Salter’s claim of noble intentions falls short: “it’s a tribute, I could have had a different one, a new child altogether that’s what most people but I wanted you again because I thought you were the best.” This begs the question, “Best of what?” and implies that the original Bernard himself was chosen already from a number of children. Salter barely flinches
when his first son admits to killing the second, even telling Michael Black "when the second one... was murdered it wasn't so bad as you'd think because it seemed fair." 47

Perhaps more important than the issue of identity is the question of nature versus nurture, a question that Salter poses out of morbid curiosity:

SALTER. ...someone with the same genetic exactly the same but at a different time a different cultural and of course all the personal... what I'm saying would he have done the same things. 48

His tone sounds eerily like a detached experimenter, almost treating his sons as observable data. Bernard Two raises the question as well, wondering if he and Bernard One would have turned out similarly had they been treated alike. At one point Bernard Two finds himself identical in behavior to Bernard One: "I remind myself of him. We both hate you," he tells his father, but hastens to add, "Except what he feels as hate and what I feel as hate are completely different because what you did to him and what you did to me are different things." 49 Even similar feelings originate in contrasting impulses. Given the disparity between all three sons, Churchill seems to argue in the direction of nurture. Salter's annoyed reaction at Black's personality seems like a condemnation of the notion that all three sons could have turned out the same.

3.7 CONCLUSION

The five plays discussed here are by no means the only worthy science plays in existence. I believe they represent the genre over the past fifty years, and demonstrate the incredible variety of structures, content, and integration of scientific elements. Each one discusses issues of science relevant to its time and place, such as Brecht's and Dürrenmatt's preoccupation with atomic physics, Stoppard's and Auburn's use of
modern mathematics, and Churchill’s treatment of the burgeoning field of genetics. Into this spectrum I now wish to fit *Copenhagen*, which has received the most critical and scholarly attention of any science play, and discuss how it demonstrates the strengths and weaknesses of the genre.
2 Brecht 125.
4 Hye 162.
5 Hye 166.
7 Brecht 63.
8 Brecht 56.
9 Brecht 85.
10 Brecht 23.
11 Brecht 129.
12 Brecht 77.
13 Brecht 124.
17 Dürrenmatt 96.
18 Dürrenmatt 74-5.
19 Dürrenmatt 96.
20 Dürrenmatt 75.
21 Dürrenmatt 76-9.
22 Dürrenmatt 48.
23 Dürrenmatt 92.
24 Dürrenmatt 93.


27 Stoppard 5.

28 Stoppard 73.

29 Stoppard 46.

30 Susanne Vees-Gulani, “Hidden Order in the ‘Stoppard Set’: Chaos Theory in the Content and Structure of Tom Stoppard’s *Arcadia*,” *Modern Drama* 42.3 (Fall 1999): 413.


33 Auburn 81.

34 Auburn 83.

35 Auburn 83.

36 Auburn 38.

37 Auburn 41.

38 Auburn 34.

39 Auburn 5.

40 Quoted in Auburn 39.


42 Churchill 7.

43 Churchill 7.

44 Churchill 9.

45 Churchill 16.

46 Churchill 21-2.

47 Churchill 49.

48 Churchill 33.

49 Churchill 35.
CHAPTER 4

MICHAEL FRAYN’S COPENHAGEN AS CASE STUDY

4.1 INTRODUCTION

Perhaps no play in recent years has generated more lively and extensive
discussion on the topic of science and theatre than Michael Frayn’s Copenhagen.
Premiering at Britain’s Royal National Theatre on May 10, 1998, Copenhagen
immediately fascinated audiences with its depth, character, and analysis of historical
and scientific fact and, since its writing, numerous symposiums and conferences around
the globe have engaged the dialectic of drama and science. These meetings frequently
revolve around the production of a science play; recurrent choices include Copenhagen,
Arcadia, Proof, and Life of Galileo.¹ What reviewers have found most attractive are
Copenhagen’s smooth dialogue and the accessibility of difficult scientific concepts.²

Copenhagen seems an appropriate fit with Frayn’s body of work. Like his
character Heisenberg, he certainly has a penchant for uncertainty, quickly evidenced in
his 1974 book of philosophy, Constructions, the first point of which begins, “The
complexity of the universe is beyond expression in any notation.”³ Later thoughts from
Constructions reflect on Heisenberg and the uncertainty principle as well as the use of
mathematics as a language: “Mathematics seems out of place here. When we talk about
our freedom like this, we are not in the realms of description… but of exhortation.”

*Copenhagen* itself invites comparison between Frayn’s latest play, *Democracy*, playing in the Cottesloe of the National Theatre as of this writing. *Democracy*, too, focuses on the difficulty in truly understanding human personalities. Frayn draws again on historical figures from Germany, this time exploring Federal Chancellor Willy Brandt and his assistant Gunter Guillame, who turned out to be a spy for East Germany.

Werner Heisenberg’s uncertainty principle features most prominently in *Copenhagen*. As previously mentioned, Frayn acknowledges that Thomas Power’s biography *Heisenberg’s War* first led him to the connections between Heisenberg’s life and science. Heisenberg’s famous principle of uncertainty states that the velocity and position of subatomic particles can never be fully and simultaneously known. To isolate one is to neglect the other. This happens when bombarding particles with powerful gamma rays; the rays freeze a particle into a position, but then the observer knows nothing about its movement, velocity, or direction. In short, pinpointing the particle tells us nothing of its natural attributes.

Niels Bohr’s complementarity principle works alongside uncertainty. To observe electrons they are bombarded with light, and the effects of the collision between the photons of light and the electrons can help describe the electron. By observing the light, a physicist can deduce how it is deflected by the electron. The problem lies in the photons’ dual attributes of both particles and waves; two completely different objects. To explore light as a wave one must use Erwin Schrödinger’s wave equation; to explore light as a particle requires Heisenberg’s matrix mechanics. However, an observer must choose to treat the photon as either wave or particle, and the
choice necessarily forsakes the other possibility. The use of Bohr’s complementarity to explore subatomic particles within uncertainty constitutes the central tenets of the Copenhagen Interpretation of quantum physics, an interpretation still in widest use today.

*Copenhagen* incorporates a further layer of using historical characters. Frayn’s own act of historical reconstruction and artistic license parallels his characters’ attempts to piece together an understanding of their past and personalities. His postscript to the play includes an important discussion of the playwright’s role in recreating human beings. As we have no possible way of knowing historical persons’ thoughts, Frayn concludes that the only way into their minds is through the imagination. *Copenhagen* could then be viewed as the final extension in the process of uncovering history; to really make history breathe before us, we must resort to both our imaginations and Frayn’s.

My exploration of *Copenhagen* will begin first with how the play’s structure and characters relate to Frayn’s treatment of quantum physics. Second, I will examine Frayn’s application of scientific theories in another attempt to quantify the human and how both he and his characters treat the role of the observer. Finally, I will invert my second point to discuss the importance of using human action to describe scientific theories.

Throughout my analysis, I will emphasize the role of explanation in *Copenhagen*. Science plays in general include varying amounts of explanation, and Frayn delineates several methods and attempts at it. It is most poignant in the historical context since Werner Heisenberg and Niels Bohr in their latter years were forced to
explain themselves and their involvement in the genesis of the atomic bomb. Then there are the efforts by Frayn, via his characters, to explain the central meeting of the play. Like a majority of science plays, *Copenhagen* incorporates a layer of explaining the science, in this case theories meant to explain the status of particles at the quantum level. Finally, there are Frayn’s attempts to explain the characters’ story using the very structure and format of the scientific theories presented. So there exist several layers in both form and content, inside and outside the play, of explanation.

I also wish to stress the element of desperation in these explanations. At the very least, Heisenberg, Margrethe, and Bohr harbor a strong desire to have things explained, to make things known, to achieve clarity. I find it very appropriate that Frayn begins the play with Margrethe’s question, “But why?” Even though these characters are “dead and gone,” existing after death – often considered a state in which all things are made clear – they still seek explanation: in the form of justification, of knowledge, and of understanding.⁵

Frayn certainly does much to raise the stakes on the characters and the audience understanding the motivations of Heisenberg, Bohr, and Margrethe. The consequences of their actions resonate on global or cosmic scales. Heisenberg recurrently ponders his role in the central story when reliving the meeting; he later thinks of himself as the one human being in two thousand million to bear important news. Margrethe observes the men’s collaboration in the 1920’s, saying, “And from those two heads the future will emerge. Which cities will be destroyed, and which survive. Who will die, and who will live. Which world will go down to obliteration, and which will triumph.”⁶ This places incredible importance on their partnership, quite literally deciding the future of the
world. Frayn stresses this in the final “draft” of the play’s action, in which Bohr and Heisenberg walk themselves deliberately through their meeting. Bohr postulates the outcome if he had corrected Heisenberg’s calculation of the diffusion of neutrons in uranium 235, and the characters realize the implication of Heisenberg’s success in creating nuclear weapons in Nazi Germany. Frayn compares the effects of Heisenberg’s mistaken calculation (or lack thereof) to the genesis of nuclear fission: “the consequences went branching out over the years, doubling and redoubling,” until the final result makes as much of an impression (metaphorically) as a nuclear explosion.²

Frayn notes in his postscript that the word “uncertainty” is a misleading translation of Heisenberg’s term. A better translation, both he and Heisenberg say, is perhaps “indeterminability.” “Indeed, the very idea of uncertainty seems to imply the possibility of certainty,” Frayn observes.³ While acknowledging the importance of proper translation, Frayn’s comments also illuminate an important point often lost in discussion of indeterminability. The uncertainty principle describes a particle’s position in terms of decreasing probabilities, i.e. a 50 percent chance the particle is in this position, 25 percent chance it is here, 10 percent chance it is here, et cetera. What uncertainty never attempts to say, however, is that the particle does not exist – and no one seems to be claiming this. Similarly, while Frayn’s characters hash out the details of that fateful meeting, never do they deny that the meeting – that some sort of “collision” – happened. Observing the effects might not reveal many specifics of the collision, but we may rest assured that a collision happened. Although even the real life Bohr and Heisenberg could not nail down details of that meeting, never has anyone doubted that the meeting happened. My point is clear by now – that recordable details, however
unclear or obfuscated by our own act of looking, still show us that something observable exists. Something happened. The particle moved. Someone took action. Perhaps uncertainty is still a useful term exactly because it points to the certainty of observation.

4.2 PLAY STRUCTURE, CHARACTER, AND THE SCIENCE

Many articles and reviews touch on the similarities between the structure of Copenhagen and the structure of an atom. Each “draft” the characters create of the 1941 meeting offers another glimpse at the particles’ whereabouts within the atom of the play; Frayn briefly shines a light on the characters, and we see them frozen in a different position of the story. Each flash reveals a small piece of a larger, unsolvable puzzle. Frayn, having forgone stage directions, leaves opportunity for the director to draw all sorts of visual metaphors in the blocking, which I will discuss in depth later.

Frayn’s very structuring of the play points toward Heisenberg’s and Bohr’s meeting as a collision, the observable effects of which form our means of intuiting what precisely happened. If we focus too much on one particular explanation, character, thought, or theory, we neglect all other data. The meeting serves as the brief moment when light pins down the particles without velocity; Margrethe names the moment as a collision in the final draft. Frayn shines the light more than once to show us several possibilities. Each time he shines it, the particles – the meeting, the personalities, the motivations – freeze in one position, in which we can describe them, but never wholly, never completely.
The characters also operate as various particles or groupings thereof at different times. I will try not to drive the point too far home, but merely explicate another layer of Frayn’s composition, and attempt to recognize what these characterizations tell us about the character and their function.

Margrethe readily serves as the nucleus of the play’s action, and the two men as electrons revolving around her. She is the element keeping the two men unromantically grounded in reality and aware of the personal slant of their arguments, In attempting to explain their history and their work they utilize her as the stable center, frequently deferring to her observations. “We’re going to make the whole thing clear to Margrethe,” Bohr says. Michael Blakemore, director of the London and New York productions, as well as Maureen Ryan, director of the Columbus production, blocked Bohr to direct Margrethe to a chair while the two men readied their debate. In point of neutrality, however, Margrethe fails -- early in the play she voices her distrust of Heisenberg -- but she cannot be faulted; she is, after all, married to the third character in the play. In a final stretch of the metaphor, then, Margrethe does not remain as the fixed center. She, too, is fissionable. Her anger, perhaps stemming from the effects of Bohr’s and Heisenberg’s “collision,” boils over and she begins voicing her opinion passionately. “Well, now you’re simply working yourself up,” Bohr chides her. “A chain reaction. You tell one painful truth and it leads to two more,” she replies. Margrethe expresses her frustration with having kept her thoughts to herself. Like an unstable nucleus, this particular observer is predisposed to become, understandably, personally involved in the observation.
While Margrethe functions most often as the nucleus, her husband receives treatment as both a nucleus and a roving electron. He needs to span both roles – as both central and orbital – to bridge the gap between Margrethe and Heisenberg. First, many descriptions of Bohr parallel his treatment as a central figure. “The Pope” he was called by many of his students, a position he later clarifies by comparing himself to Albert Einstein: “Einstein, you see? – I’m the Pope – he’s God.” Heisenberg recalls Bohr’s designation by members of the Los Alamos project: “Oppenheimer described you as the team’s father-confessor.” Historically, Niels Bohr was very often described as a father figure – stable, resolute, and reliable. No wonder, then, that Heisenberg would describe Bohr at his institute as a nucleus, his students as electrons on different orbits, the inmost orbit occupied by the favorite student. In order for this experiment to work, though, Bohr must also be allowed to wander freely. He and Heisenberg move sporadically in their indeterminate orbits, simultaneously together and apart, thus allowing them to collide at the point of their meeting. Heisenberg describes a brooding Bohr as a particle whose whereabouts and intentions cannot be determined.

It is tempting to view Heisenberg as the play’s central character. He, after all, instigated the 1941 meeting, clearly going to Bohr in unusual circumstances with something important to say. Frayn explores the multiple facets of his motivation: he is under surveillance by the Gestapo, torn by his love of science and love of Germany, and dislike of war and Nazism, under pressure from his family and his fellow scientists, and shouldering a part of the burden of discovery. So Frayn’s comparison of the inscrutability of particles and that of Heisenberg’s motivation seems fitting.
One of the most outstanding and frequently cited examples is Fraun’s comparison of Heisenberg’s skiing to his scientific conduct. Heisenberg clearly operated at a faster pace than Bohr. In the story told, Heisenberg would race Bohr and Carl von Weizsacker (a fellow German physicist – often paired with Heisenberg as Heisenberg was to Bohr) during supply runs down the mountain from their hut in Norway. Heisenberg, in his competitive spirit, would blur down the hillside in eight minutes, while Bohr would safely pick his way in forty-five. Bohr finds this comparable to Heisenberg’s science – arriving at a conclusion quickly, concerned only that the experiments produced results. Bohr, on the other hand, marched slowly but steadily through the mathematics, “digging all the capsized meanings and implications out of the snow,” as Heisenberg quips.\(^{18}\) More concerned with the consequences of the results and how they fit into the larger picture, Bohr is preoccupied with conveying the results properly to those around him: “But the question always is, What does the mathematics mean, in plain language?”\(^{19}\) Heisenberg, he argues, never stopped to think about the consequences of his findings.

Bohr also applies this story to explain a particle’s behavior described by uncertainty. “At the speed you were going you were up against the uncertainty relationship,” he tells Heisenberg. “If you knew where you were when you were down you didn’t know how fast you’d got there. If you knew how fast you’d been going you didn’t know you were down.”\(^{20}\) In the case of skiing, and perhaps scientific observation and life observation in general, this poses a danger, Bohr implies. A reckless speed
denies one knowing and understanding everything necessary. Too narrow of a focus on speed forsakes knowledge of one’s position, and vice versa. In the physical act of skiing, this could mean death.

Similarly, Margrethe extends the anecdote to Bohr and Heisenberg’s thought-experiment regarding particles of light. The particle, passing through diffraction grating, seems to go through two slits at once. While skiing high speed, argues Heisenberg, a person theoretically exists in two places at once. If a skier approaches a precipice, he must “Swerve left? Swerve right? Or think about it and die?” he poses. “In your head you swerve both ways....” The person hypothetically exists in several different possibilities, he says, at which point Margrethe offers that the skier has swerved both ways, gone through two different slits like the particle, made both decisions, and yet comes back together as one, on the other side of the precipice.  

4.3 QUANTIFYING THE HUMAN IN SCIENTIFIC TERMS

Margrethe’s ominous opening inquiry of “But why?” sets the tone for a heuristic question asked in Copenhagen and most science plays: how do we understand ourselves – the depth of our memory, the reliability of history, the implications of discovery, the breadth of motivation? Frayn in particular answers that we never can know, that the dimensions of the human mind can never be measured, regardless of our methods. Even Heisenberg, agent of the action in the 1941 rendezvous, may not have known what drove him there: “I doubt if he ever really knew himself,” comments Bohr. But
perhaps each play discussed here can aid understanding by use of metaphor. Metaphor, after all, is another form of explanation. Here Copenhagen demonstrates the beauty of scientific metaphor applied in a literary context.

Frayn frequently employs scientific theory and terminology to describe human relationships. Often subatomic particles merit description in pairs, combined because of electric charges, ionization, et cetera. Likewise, certain human beings are best described in pairs, and the application of scientific terminology may indicate something about the strength of the connection.

The first application needs only brief description, as I mentioned earlier. Bohr and Heisenberg’s relationship receives several different renderings in Copenhagen, described separately as “chairman and managing director,” “father and son,” and later even as the Pope and a leading cardinal. The implication is of two dependent members of a pair. Margrethe expresses another important designation of the men’s pairing. Bohr and Heisenberg celebrate their achievements from their partnership at Bohr’s institute in Copenhagen, developing the Copenhagen interpretation, which combines the tenets of uncertainty and complementarity. Yet while Bohr and Heisenberg consider themselves to have worked out the theories together during endless conversations and walks, Margrethe reminds them that development of the individual ideas occurred while they worked apart. Their intense personalities frequently required separation. Heisenberg, Margrethe points out, worked out quantum mechanics while on the island Heligoland in the middle of the North Sea, having apparently gone there to escape summertime bouts of hay fever. Bohr similarly escaped to Norway, where he figured out complementarity
while Heisenberg finalized his uncertainty paper back in Copenhagen. The two physicists accomplished their work together and apart, behaving much like the single particle passing through two slits simultaneously, in two places at once. The famous partnership operated while the two lived simultaneously in Copenhagen and spread out across Europe.

When Heisenberg voices his jealousy of Bohr's and Margrethe's marriage, Bohr uses a very poignant and touching mathematical reference to describe the intimacy of their relationship: "I was formed by nature to be a mathematically curious entity: not one but half of two."25 The pairing of two particles or numbers takes on a greater meaning in implying that each constitutes only half of the whole. This lays significant meaning to the need for the other and the sense of one's incompleteness without a partner.

Finally, Heisenberg broadens the description of relationships to include his home of Germany. Bohr expresses suspicion over the German Foreign Service since it is a department of the Nazi government, to which Heisenberg rejoins, "Germany is more complex that it may perhaps appear from the outside."26 This simple reply seems like a metaphorical application of the atomic model to the country. The atom functions as a whole, yes, although the individual components may independently adhere to their own traditions despite endeavors to reform, says Heisenberg. The Foreign Service, for instance, detaches itself and models autonomous behavior like an electron breaking an orbit: we later learn that through the Foreign Service many Danish Jews received forewarning of their deportation and made an escape.
Frayn draws frequent comparisons between the difficulty in situating human thoughts and subatomic particles. “What the uncertainty of thoughts does have in common with the uncertainty of particles is that the difficulty is not just a practical one, but a systematic limitation which cannot even in theory be circumvented,” he says in the postscript to the play.27 Like the observation of particles, there simply exists no workable method of recording empirical data.

This limitation forms one of Frayn’s central ideas of the play (not to mention a celebration of the writer’s role):

The great challenge facing the storyteller and the historian alike is to get inside people’s heads, to stand where they stood and see the world as they saw it, to make some informed estimate of their motives and intentions – and this is precisely where recorded and recordable history cannot reach. Even when all the external evidence has been mastered, the only way into the protagonists’ heads is through the imagination. This indeed is the substance of the play.28

We are dealing with the realm of the completely unknowable. Even explanations offered by individuals must be treated as suspect, for we, perhaps least of all, understand our own thought processes and intentions.

Frayn couples this with discussion of the multiplicity of thoughts. His characters are shown – like all humanity – oftentimes to endure uncontrollably complicated thinking. “So many things we think about at the same time,” mutters Bohr. “All the things that come into our heads out of nowhere,” Margrethe adds.29 Frayn demonstrates these moments of busy brain activity by the occasional reference to the drowning death of the Bohrs’ eldest child Christian. These moments utilize the simplest verbal expression, but seemingly the most complex mentally. The characters pause (directors Blakemore and Ryan slowed the pace) after heated discussion, perhaps mulling over the
complexity of their recent debates and recollections while simultaneously entertaining thoughts on things better left unsaid.

These thoughts are often born out of the variety of obligations pressuring an individual. We have so many sets of responsibilities that perhaps they begin canceling each other out, or at least making one’s true motivation impossible to pinpoint. Heisenberg utilizes complementarity and the particle’s pass through the diffraction grating to explain this impossible multiplicity of motivations:

Complementarity, once again. I’m your enemy; I’m also your friend. I’m a danger to mankind; I’m also your guest. I’m a particle; I’m also a wave. We have one set of obligations to the world in general, and we have other sets, never to be reconciled, to our fellow-countrymen, to our neighbors, to our friends, to our family, to our children. We have to go through not two slits at the same time but twenty-two. All we can do is to look afterwards and see what happened.30

He describes Bohr’s possible reaction to Heisenberg’s comments during the famous visit. If, Heisenberg supposes, Bohr had suspected him of arming Hitler with nuclear weapons, why did not Bohr simply kill him? Yet the intention can never be that clear. Bohr must balance love of a friend with love of country, obligations of hospitality with those of wartime, and so on, repeated to inscrutability.

Sometimes one might desire to remain indeterminate, as Margrethe accuses Heisenberg of being. “Your talent is for ski-ing too fast for anyone to see where you are,” she tells him. “For always being in more than one position at a time, like one of your particles.”31 Some individuals may desire to remain a mystery – a romantic notion, to which Heisenberg was susceptible. Heisenberg, Margrethe says, had a weakness for uncertainty.
Frayn also addresses the often uncontrollably rapid pace of human thought. Bohr repeatedly criticizes Heisenberg for jumping to conclusions. Heisenberg, he says, thinks exactly how he skis, neglecting the means when seeking the ends. At one point Bohr interjects, “Not so fast, Heisenberg... Not so fast, not so fast!” as Heisenberg draws conclusions to the end of an experiment. Likewise, Heisenberg accuses Bohr of jumping to conclusions. The moment Heisenberg first hints to Bohr the possibility of a German atomic bomb, Bohr storms off without awaiting further explanation. “At this point you had stopped listening,” Heisenberg cries, “The bomb had already gone off in your head.” The characters’ thought processes make split-second detours, like the skier approaching an abyss. Characters take action without pausing for thought and reason out the implications of the decision afterwards.

Frayn also draws the metaphor of human thoughts as the particles of physics, considering them impossible to pin down, like the electrons moving about in their clouds surrounding a nucleus. Even the slightest interruption, like a passing photon of light, disturbs any possible cohesion. In the final draft of their meeting, Bohr and Heisenberg describe the fleeting nature of Heisenberg’s thoughts:

BOHR. Until this instant his thoughts have been everywhere and nowhere, like unobserved particles, through all the slits in the diffraction grating simultaneously. Now they have to be observed and specified.
HEISENBERG. And at once the clear purposes inside my head lose all definite shape. The light falls on them and they scatter.

Frayn expresses this difficult concept very easily through the metaphor of subatomic particles under scrutiny by the uncertainty principle.
Ultimately, Frayn conveys the inexpressibility of human thought and motivation poetically in the term “Elsinore.” “The whole appearance of Elsinore, you said,” Heisenberg tells Bohr, “was changed by our knowing that Hamlet lived there. Every dark corner there reminds us of the darkness inside the human soul....”35 The characters find this darkness of the soul difficult to define, and use it as the explanation for reckless behavior, which should seem uncommon from such mathematical minds. Heisenberg confesses “Elsinore” as his motivation for balancing atop a Japanese pagoda in high winds; Bohr admits likewise for having thrown stones at a washed-up mine during a walk with a student.36 Margrethe later stresses the importance of this darkness’ role:

MARGRETHE. Really it is ridiculous. You reasoned your way, both of you, with such astonishing delicacy and precision into the tiny world of the atom. Now it turns out that everything depends upon these really rather large objects on our shoulders. And what’s going on in there is....

HEISENBERG. Elsinore.
MARGRETHE. Elsinore, yes.37

Since measurement and observation depend on human agency, she asserts, understanding the darkness of Elsinore is key to comprehension of their scientific principles. This darkness is the uncertainty of humanity, of what makes us do idiotic things such as pointlessly endangering our lives. Like Frayn’s necessary use of imagination to finally explicate his characters, their final expression must be poetic and imaginative in form, while linked to the physical space both of the Castle Elsinore and the atom itself.
We must note, alongside *Copenhagen*’s helpful explorations of the human mind, the moments when Frayn shows us the failure of science to account for human action. The necessary use of the term “Elsinore” to describe thoughts and motivations serves as a first example: no scientific theory could affix proper meaning to that indescribable darkness causing such bouts of illogical behavior. Similarly, when attempting to specify Heisenberg’s motivations for coming to Copenhagen, Bohr begins: “Let’s add up the arguments on either side in a reasonably scientific way. Firstly, Heisenberg is a friend…” “Firstly, Heisenberg is a German,” Margrethe interrupts. Even when employing a “scientific” approach, the two observers cannot agree on defining the first point.38

“Mathematics becomes very odd when you apply it to people,” Heisenberg muses. “One plus one can add up to so many different sums.”39 Niels’ and Margrethe’s failed attempt to summarize Heisenberg mathematically betrays the idea that mathematics works as an infallible language, even though Heisenberg (who would prefer to speak purely in differential equations, Bohr notes) argues for it:

**HEISENBERG.** What something means is what it means in mathematics.
**BOHR.** You think that so long as the mathematics works out, the sense doesn’t matter.
**HEISENBERG.** Mathematics is sense! That’s what sense is!
**BOHR.** But in the end, in the end, remember, we have to be able to explain it all to Margrethe!
**MARGRETHE.** Explain it to me! You couldn’t even explain it to each other!40

So Bohr and Heisenberg, two skilled users of mathematics as a language, could not even properly explain the concepts to each other. How, then, could they possibly
convey the theories to a relatively unskilled user like Margrethe, or the world at large?
Clearly the characters need to find a better language for explaining themselves and their
work.

Later, Heisenberg demonstrates another failure in his recollection of Bohr
winning a game of poker with a straight he never had. "I thought I had a straight! I
misread the cards! I bluffed myself!" Bohr cries. He saw an organization in the cards
that did not exist, and, believing it, raised the other players so high that "our faith in
mathematical probability begins to waver, and one by one we all throw in," says
Heisenberg.41 Such is the result of Bohr's mistaken observation -- he reads his cards
with a misguided certainty. In his case, the mistake led him to bankrupt his opponents,
but imagine the greater implications of following a mistaken path with such certainty.
The latter insinuation is that Heisenberg, misguided by his own faulty assurance, might
have built an atomic bomb for the Nazis or accidentally killed himself in the rush to do
so.

Already we have had to resort to a poetic, literary reference to accurately
describe the human mind. Now, some particulars of its workings come into question.
The protagonists' attempts to remember the past meeting comprises the central exercise
of Copenhagen. Frayn clearly demonstrates how the historical characters of Bohr and
Heisenberg understood differently what happened during the 1941 meeting. Each is
recorded to have offered several different -- and even conflicting -- accounts of the
meeting.42 Early in the play, as the protagonists take the stage, the three of them
comment:
BOHR. A curious sort of diary memory is.
HEISENBERG. You open the pages, and all the neat headings and tidy jottings
dissolve around you.
BOHR. You step through the pages into the months and days themselves.
MARGRETHE. The past becomes the present inside your head.\textsuperscript{43}

Heisenberg’s line in particular emphasizes the difficulty in organizing memory. “All the
neat headings and tidy jottings dissolve” whenever we attempt to explore the meaning
and content of a memory. The recordings of our five senses betray us when we later try
to access them.

Frayn employs an excellent example in the ambiguity of memory. Bohr and
Heisenberg argue over Bohr’s experiment with a colleague using cap guns. The
intention was to prove the primacy of acting over reacting. Each physicist, armed with a
cap pistol, went about the day until an argument broke out between the two. In the heat
of the moment, Bohr’s colleague reached for his pocket, which elicited Bohr’s response
of withdrawing his cap pistol and firing. The problem arises while telling the story as to
which physicist Bohr shot – Hendrik Casimir or George Gamow. Heisenberg and Bohr
argue halfheartedly back and forth, Bohr remembering Gamow, Heisenberg saying he
heard the story from Casimir. Bohr resolves the point only by admission of ambiguity,
remarking, “Yes, well, one of the two.”\textsuperscript{44}

Frayn also demonstrates the malleability of memory and the power of
suggestion over it. Heisenberg attempts to sort details of his memories and demonstrates
that the position of the observer affects the outcome of his experiment. As he tries to
recall the attendance at a meeting in Bohr’s institute, he begins picturing faces and
realizes that he is unconsciously assigning them:
No chance to talk to Bohr, of course. Is he even present? There’s Rozental… Petersen, I think… Christian Moller, almost certainly… It’s like being in a dream. You can never quite focus on the precise details of the scene around you. At the head of the table – is that Bohr? I turn to look, and it’s Bohr, it’s Rozental, it’s Moller, it’s whoever I appoint to be there….\textsuperscript{45}

Enacting his own theory, Heisenberg focuses too closely on one face and loses all others. Like a physicist deciding whether to treat light as particles or waves, Heisenberg makes a choice about who he hopes to see. Having made the choice, he looks and sees who he expected. Similarly, the physicist, when conducting an experiment involving light, must choose whether to employ Schrödinger’s wave equation or Heisenberg’s matrix mechanics. However, the use of Schrödinger’s equation automatically results in treatment of light as a wave; the same occurs when using matrix mechanics: the outcome indicates light as a particle. The physicist’s predetermined biases dictate the outcome of the experiment, even if the biases were forced. Likewise, when Heisenberg turns to look who sat next to him, the person he expects to see will always be there.

A passage from Frayn’s \textit{Constructions} elucidates the details of reconstructing memories. Frayn relates a story of a plane landing one night, when three tires burst on touchdown and emitted a bright shower of sparks. In recounting the panicked moment when the tires ruptured, he realizes that certain details like his seat location, faces of nearby passengers, and his thoughts remain unclear. When he next re-imagines the scene, he fills in those details, despite possible inaccuracies. For instance, he saw the sparks contrasting the darkness, but he quickly realizes that there must have been bright lights on the wingtips, so the background could not have been perfectly dark.\textsuperscript{46} The
passage demonstrates his point of our mistaken reconstruction of the past. We fill in particulars because we cannot remember them, he says, then begin to believe them. When a piece has gone missing, we reconstruct it accordingly and in great detail.

Margrethe often adds a personal touch to the discussions, filling in emotion where Niels and Werner have gotten too scientific. It may simply be a maternal role she fulfills – after all, she completes the family dynamic created by treating Bohr and Heisenberg as father and son – but she serves another function. The two physicists may simply be forgetting the emotional element or romanticizing the past. Margrethe summarizes it:

You want to make everything seem heroically abstract and logical. And when you tell the story, yes, it all falls into place, it all has a beginning and a middle and an end. But I was there, and when I remember what it was like I’m there still, and I look around me and what I see isn’t a story! It’s confusion and rage and jealousy and tears and no one knowing what things mean or which way they’re going to go.47

She again plays the quasi-neutral observer, reminding Heisenberg that the development of his uncertainty principle might have had a simple human motivation behind it. Heisenberg may have been jealous of Schrödinger’s popularity with his wave equation and wanted to stake some ground for himself. Until then, his motivation has been heroic, noble, serving humankind and defiant to the Nazi regime. But, as Margrethe observes, Elsinore was there: “confusion and rage and jealousy and tears.” This recalls the story of Bohr and Casimir behaving like children playing with their toy guns; the physics at Bohr’s institute was not always intelligent men engaged in composed conversation.
In response to the uncertainty and unreliability, Frayn’s characters still make several attempts to control the circumstances. Indeed, the whole play could be seen as their endeavor to finally impose structure on the past. Surely an immersion into so much uncertainty would breed a desire for some stability. This reflects the metaphor of a nuclear reaction and its stability (or lack thereof). We might extend this metaphor by pointing out that Frayn’s physicists deal with two different types of reactors, one a controlled and self-sustaining nuclear reactor, the other a chain reaction of events that spirals out of control into an atomic explosion. While a reactor may be deliberately initiated, the great fear persists of nuclear power going beyond our control. Hence the justifiable stigma attached to nuclear power plants, in light of accidents such as Chernobyl. The event central to this metaphor is Heisenberg’s work on the German reactor program, eventually relegated to a hole dug in the ground. His obsession with getting the reactor up and running is evident in his description of the events: “We were almost there! We had this fantastic neutron growth! We had 670 per cent growth! … Another week. Another fortnight. That’s all we needed!” Bohr forces him to admit that he and his team possessed a rudimentary understanding of the dangers. They had nothing to shield themselves from the radiation when the uranium finally reached its critical mass, and their only weapon to slow an out-of-control reaction was a lump of cadmium. Yet Heisenberg insists he maintained control of the program. Ultimately, the control comes in the form of another human being. Bohr refers to himself as Heisenberg’s “own walking lump of cadmium,” a catalyst who slows Heisenberg’s process, who compels him to stop and think.49
Frayn also enters into the discussion, as did Bohr and Heisenberg, of the philosophical implications of science. Surely this warrants a place in quantifying the human; philosophy, after all, is another human attempt at understanding our place in the universe. Frayn outlines the argument in Bohr’s speech summarizing the repercussions of their work in the early twentieth century, but I would like to focus instead on the philosophical importance of Bohr’s and Heisenberg’s work. Already we have seen the global and political implications; now Frayn widens the scope to the metaphysical. Suddenly this passing incident in 1941 takes on the significance of humankind’s place in the universe. There are three specific, loosely philosophical implications I would like to explore: the denial of causality, the balance between scientific results and their implications, and the role of paradox.

The first is the negation of causality. Einstein’s relativity and Heisenberg’s uncertainty claim that measurement and observation become notoriously difficult at high velocities and on the microscopic scale. However, an ultimate ambiguity at the quantum level suggests the same for the world on a larger scale. Heisenberg describes it best:

The theoretical point remains, though, that you have no absolutely determinate situation in the world, which among other things lay waste to the idea of causality, the whole foundation of science – because if you don’t know how things are today you certainly can’t know how they’re going to be tomorrow.}

This ties in with basic tenets of chaos theory, particularly in saying that one cannot accurately account for the present movement of atoms, objects, et cetera, therefore leaving one with no way to predict what will happen in the future, or more importantly, what led to the present circumstances.
And where, Frayn asks, lays the balance between the importance of scientific advance and the importance of its implications? Frequently this old discussion of means versus ends and whether one justifies the other is mistaken for the central theme of the play, materialized into the ethical implications of developing atomic energy. Frayn himself, however, has warned against this and insists his theme goes beyond an ethical argument.\textsuperscript{51} Heisenberg and Bohr accuse each other separately of focusing too narrowly on the ends:

\begin{quote}
BOHR. I said wave mechanics and matrix mechanics were simply alternative tools.

HEISENBERG. Something you're always accusing me of. 'If it works it works.' Never mind what it means.

BOHR. Of course I mind what it means. ... Somewhere inside you there are still secret reservations [about complementarity].

HEISENBERG. Not at all -- it works. That's what matters. It works, it works, it works!\textsuperscript{52}
\end{quote}

This particular point applies as of this writing, especially concerning our speed in developing technology and whether society can handle it. The difficulty, again, is the hand-off. The development -- the means -- may not itself have been bad, but the general public may not be prepared for practical application -- the ends.

Finally there is the place of paradox in science. The necessary use, according to complementarity, of differing treatments of particles as particles or waves, requires one's comfort with a degree of paradox. Paradox itself -- the possibility of two or more possibilities existing at once -- celebrates what makes us human. A set of numbers or a computer could never balance out the two, but the human mind can accept and even enjoy paradox. Likewise, the two physicists wrestle with their ability to work within paradoxes.
BOHR. It was a fascinating paradox.
HEISENBERG. You actually loved the paradoxes, that’s your problem. You
reveled in the contradictions.
BOHR. Yes, and you’ve never been able to understand the suggestiveness of
paradox and contradiction. That’s your problem. You live and breathe
paradox and contradiction, but you can no more see the beauty of them
than the fish can see the beauty of the water.53

This passage demonstrates differing abilities to work with paradox. Funny that
Heisenberg should come across as relatively incapable of dealing with paradox, despite
his general affinity for uncertainty, even though the paradoxical differs from the
uncertain.

4.4 THE OBSERVER INVOLVED

The uncertainty principle, and Frayn in *Copenhagen*, place strong emphasis on
the role of the observer in scientific experiment. One role of critical theory is addressing
the bias or preconceived perspective that an observer brings — willingly or not — to the
act of observation, exemplified in the construction of history, relation of a story, or
argument of a point. In his postscript, Frayn notes that the playwright, who attempts to
create human characters on stage, must ultimately rely on the imagination to succeed.
To truly enter a person’s mind, especially someone deceased, is impossible. That
person, the play argues, cannot even truly know him or herself. Since the importance of
observation surfaces in the play and its topic, I will briefly discuss the different facets of
observation that Frayn includes. These bear relevance to a person’s efforts at self-
exploration; to explain oneself, one must be able to observe one’s actions. The
explainer is necessarily involved in the observation, for he or she has something at
stake, an agenda to prove.
Like discerning particles’ attributes by the light reflecting off them, we can judge people only by external effects – by what they say and what they do. However, in order to fully understand their external effects, we have to consider an impossibly large number of facets of that person, and if we focus too closely on one characteristic, we completely lose sight of their multiple dimensions. This is Bohr’s exact understanding of particles using the complementarity principle: they must be thought of as two different things at once, both as a particle and a wave. “They’re either one thing or the other,” he says, “They can’t be both. We have to choose one way of seeing them or the other. But as soon as we do we can’t know everything about them.” He demonstrates this through his incessant pacing on stage (as dictated through dialogue), allowing Heisenberg to take complementarity a step further. Bohr’s orbit, Heisenberg says, is determined by both his “genes and the various physical forces acting on you” and Bohr’s own “entirely inscrutable whims.” A conflict ensues involving nature versus nurture: Bohr is not only a product of his surroundings but also a product of his internal predisposition. Either way, observation by external effect is a complicated step involving an element of guesswork, despite all attempts to avoid it.

After World War II, many people found themselves in the position of having to defend their actions. Heisenberg, Bohr, and many of the other physicists – on both sides of the war – found themselves explaining their involvement in the success or failure of atomic weapons. The difficulty in judging human beings based on external effects is that, as Frayn says, their internal workings are the most influential in regards to action and yet the most difficult to ascertain:
My play is an attempt to come finally at the epistemological difficulties rather than the moral ones and that the epistemological ones underlie the moral ones. You can’t get at the moral ones, you can’t make judgments about the behavior of people, until you can be reasonably confident about why they did what they did.⁵⁶

Consider Heisenberg and Bohr, he says. More questions have been raised about Heisenberg’s ethics than Bohr’s, yet Heisenberg had no hand in the atomic bomb, unlike Bohr. Based on observable evidence, Bohr is thousands of times more condemnable, creating a double standard in ethical judgment.⁵⁷

Frayn demonstrates this in some of the most famous lines of the play. Bohr begins, “Heisenberg, I have to say – if people are to be measured strictly in terms of observable quantities....” “Then we should need a strange new quantum ethics,” Heisenberg completes.⁵⁸ Whereupon Heisenberg relates a central anecdote to the play, a true experience from the final days of the European front. Traveling across Germany to reach his family in Bavaria, he encountered an SS officer, one of “a band of fanatics with nothing left to lose” accusing travelers of desertion and shooting them out of hand.⁵⁹ Here all the theories and debates coalesce into the telling of Heisenberg’s tale. The SS man, weary and apathetic, reaches for his holster to shoot Heisenberg. Heisenberg, thinking as quickly as his skiing, never stopping to explore his options, fumbles out a pack of Lucky Strike cigarettes. The cigarettes placate the SS man, who allows Heisenberg to go unharmed. Based on this act, the SS man’s actions alone demonstrate humanity and mercy, but what cannot be observed, yet must be taken into account, are his motivations. Determining these motivations would require intricate reasoning, this “strange new quantum ethics” of Heisenberg’s.
Heisenberg’s line has been used by several scholars to critique the play, most notably Jonothan Logan’s article using the line as the title, in which he debates Frayn’s historical accuracy.\textsuperscript{60} Perhaps the suggestion is that we might only analyze Frayn by the external effects evident in his writing. And if we are to judge him by \textit{Copenhagen}, what could we say about his research and creative use of the subject matter? Frayn, however, has responded to these allegations and suggests that these critics misunderstood the irony behind Heisenberg’s line.\textsuperscript{61}

Frayn’s characters also make observations about each other based on external evidence, leading to incorrect assumptions and responses. Heisenberg and Bohr, we find out, unconsciously egged each other on during rounds of table tennis. Each admits fiercely playing to win and basing their motivation on their opponent’s face. “You couldn’t see the expression on your face,” Heisenberg tells Bohr. “I could see the expression on yours,” Bohr replies.\textsuperscript{62} These judgments were perhaps a catalyst in the intensity of their relationship. Historically they collaborated well, though not without moments of intense strife, which may have set the stage for the meeting in 1941 to sour so quickly.\textsuperscript{63} For an example of their earlier instability and misjudgment, this passage of dialogue serves well:

\begin{quote}
HEISENBERG. Good God, at one point you literally reduced me to tears! 
BOHR. Forgive me, but I diagnosed them as tears of frustration and rage. 
HEISENBERG. I was having a tantrum? 
BOHR. I have brought up children of my own.\textsuperscript{64}
\end{quote}
The relationship of father and son again surfaces, along with all the associations of a parent and a child and vice versa. Judging by externals, Bohr saw Heisenberg as a child throwing a tantrum. Heisenberg, in turn, perceived Bohr as condescending like a parent. The external effects lead them to incorrect conclusions.

One of the only cases in which drawing conclusions based on visible evidence works seems to be in the practice of physics itself. The Copenhagen Interpretation works, Bohr says, because it alone explained the external effects. No other interpretation in physics fully accounted for the available evidence. However, use of this scientific theory to explore the human being fails. It even becomes a simple lesson in judging books by their covers. As Frayn has shown using Heisenberg’s story about the SS officer, we cannot properly judge a person by their appearance, actions, or words. While we must take these into account, we must always consider the motivation behind such words and actions. An evil intention behind a good word changes the effect of that word.

The difficulty facing an observer in an experiment is that the act of observation affects the outcome of the experiment. Observing electrons, for instance, involves introducing a particle of light or molecule of water vapor, which have “an energy of their own” and will participate in the action.\textsuperscript{65} The implication here is quite clear, particularly in relation to recollection and reconstruction: we recreate the past through the filter of the present, inescapably applying what we now know, accidentally filling in details.
If we continue to push the metaphor of characters as particles, Margrethe would constantly fail at being a stable center, the role in which Bohr and Heisenberg first place her; at times she seems capable of maintaining detached observation, other times she breaks her silence and steps into the action (and who can blame her in the face of Heisenberg’s forwardness?). Occasionally she lashes out against Heisenberg, accusing him of transferring his moral burden onto Bohr. Her questions and observations interact with the discussion between the two men, and influence the proceedings. This could easily be her intention, however, to focus the action toward answering the question.

In addition to being inadvertently involved in observation, the observer is also variously limited in his or her capacity to draw conclusions from observation. In Bohr’s significant speech describing humanity’s role in the universe, according to physics, he explains Einstein’s contribution. Measurement, the means of observation and basis of scientific experiment, is shown to be a fallible human act, affected in part by the measurer. He ascribes the imperfections of the human being – our biases, our mistakes, our incomplete judgments, our often unreliable five senses – as the root of measurement’s shortcomings.

At times, however, our obscured observations may be limited intentionally. When they first meet, Bohr and Heisenberg cannot fully see each other – literally and figuratively – because they do not turn to look. “But now the moment has come,” Margrethe observes, “they’re so busy avoiding each other’s eye that they can scarcely see each other at all.” We may prefer to dawdle with the questions rather than uncovering the answers, which could lead to us deliberately complicating our perspective. This, perhaps, was Heisenberg’s intention during the German atomic
energy project. He may have intentionally obscured data and left questions unanswered because arriving at an answer would result in drastic action beyond his control. Whether he really did so or not, it clearly demonstrates again that controlling the act of observation is a form of power.\footnote{67}

Even if capable of pinpointing ourselves as the root of poor observation, however, we may be unable to do anything about it. Margrethe takes her husband’s speech about placing man at the center of the universe and likens man to the observer unable to observe himself: “If it’s Heisenberg at the center of the universe, then the one person that he can’t see is Heisenberg.”\footnote{68} Frayn has articulated this idea as one of the central themes of \textit{Copenhagen}.\footnote{69} He took his cue from Heisenberg’s various explanations of his visit to Copenhagen; like Bohr, he seems to have offered several different versions. So it seems that Heisenberg was quite unable to observe himself. “What did Heisenberg tell Niels – what did Niels reply?” Margrethe remarks, “The person who wanted to know most of all was Heisenberg himself.”\footnote{70} The play could be seen as a voyage of self-discovery for all three characters.

There is suggestion, however, that Heisenberg may have actually held himself back, either consciously or not; but the act could be described as a moment of self-observation. Margrethe voices the thought in regard to Heisenberg’s passive resistance to the Nazi government. He could have leapt into the action, perhaps joining the plot against Hitler, but he felt that reserved resistance was the better route. For once, he held himself back, able to observe and assess by removing himself objectively. Michael Blakemore, director of the New York and London productions, added two rows of
seating at the back of the stage, thus creating audience members – observers observed – who were seen by the rest of the audiences. This staging technique provides a visual parallel to the idea of an observer who can observe part of him or herself.

The only other times we can make an informed observation is after the moment for decision has passed, although Margrethe reminds us that objectivity still exists in varying degrees, even after the fact. “After you’ve done it…” Bohr offers, “You look back and make a guess, just like the rest of us,” Margrethe concludes, “Only a worse guess, because you didn’t see yourself doing it.”71 The observer still remains unobserved, although with a lesser chance of remaining so once the focus has passed. “All we can do,” Heisenberg offers, “is to look afterwards, and see what happened.”72 It might be fitting to view Frayn’s postscript and post-postscript as attempts to observe after the play has happened and offer any explanation possible. Even he could not predict the effect of the audience’s interaction, and can only make guesses as to its effect later.

The characters make several attempts to construct an unobserved version of the story, which is proven impossible by their involvement in the telling and – for Bohr and Heisenberg – by Margrethe’s presence. This, of course, invokes a theoretical question similar to the conundrum of the tree falling in the woods. What happens when no observer is present? Does the event still happen or produce any effects? “I’ve typed out so much in my time about how differently particles behave when they’re unobserved,” Margrethe muses as she speculates Bohr’s and Heisenberg’s position on their walks.73 In the case of Copenhagen, all theorizing about unobserved particles is for naught; the characters find it impossible to construct an unobserved, objective version of the events.
“Let’s start all over again from the beginning,” Bohr says grandly, “No Gestapo in the shadows this time. No British intelligence officer. No one watching us at all.” After death, these ghosts would have achieved their goal, except for one thing: “Only me,” says Margrethe.74 An observer always stands ready to interpret the actions.

Heisenberg, however, defers to the supposedly objective observers of the British Intelligence agents recording the guests at Farm Hall, but these “unimpeachable witnesses” turn against him.75 After World War II, British Intelligence rounded up Heisenberg and most of Germany’s leading physicists and held them, peacefully, in a house in the English countryside known as Farm Hall. While the physicists lived and talked together for several months, British Intelligence recorded every word. Heisenberg’s appeal to the recordings reveals the errors he made in calculating the diffusion of fast neutrons in uranium 235, perhaps his most egregious miscalculation (deliberate or not), the motivation behind which makes the subject of the most scholarly speculation. So his appeal to objective sources turns on him. The Farm Hall transcripts cannot be considered objective anyhow; the texts remaining are those translated and deemed worthy of comment by the British minders.76 Already the objective record has been subjectively altered and paraphrased.

Frøyn lastly demonstrates the observers’ effect of the action through the metaphor can be drawn through staging the play before an audience. Each member of an audience interacts with the play, notices different details, forms their own interpretation, and affects the final outcome. Michael Blakemore summed up the metaphor in an interview:
Putting on a play is itself a scientific experiment. You go into a rehearsal room, which is an atom of sorts, and then a lot of these rather busy particles, the actors, do their various turns and circles about the nucleus of a good text. Then when you're ready to be seen, you sell tickets to a lot of photons. ... Then something very strange happens, because what you rehearsed in the rehearsal room and have seen a hundred times is put on a stage and a thousand pairs of eyes hit it and alter it. The energy they bring to it, the energy of their laughter or their rapt attention, changes what is there.\textsuperscript{77}

He puts it rather succinctly from the director's point of view, someone who has observed the play numerous times, only to see it change when under scrutiny by an assembly of observers. Victoria Stewart incorporates the multiplicity of readings in theatrical performance and likens them to observation within scientific experiment:

"What you understand to have taken place there is similarly dependent on a mass of contingencies. No two accounts or 'readings' of a particular performance will ever be the same; and performances themselves are not repeated, but iterated."\textsuperscript{78} The audience affects the action -- the experiment -- through their interpretation. They decide, variously, the meaning, the intention, and the outcome.

4.5 EXPLAINING SCIENCE WITH HUMAN INTERACTION

My final observations deal with how characters physicalize the science on stage in \textit{Copenhagen}. We have spent so much time applying uncertainty and complementarity to people, now we must examine what happens when you apply people to quantum theory. My concern with exploring how playwrights explain science leads me to these moments of clarity, when vast scientific concepts are most lucid, not when they try to explain human behavior, but when human behavior explains them. Heisenberg would be proud, because Frayn illuminates the science by observing the external effects of
human action and using that to clarify the principles. Most importantly, these explanations seem to take place out of exasperation and as a last resort. Heisenberg frantically defends himself and his principle of matrix mechanics, but fails under Margrethe's withering judgment. Finally, when he is on the stand, he resorts to demonstrations of the science using the physical bodies on stage and describing them by human action.

"It's not always easy to explain things to the world at large," Heisenberg admits in the play. "Explaining and defending myself was how I spent the last thirty years of my life." The real-life Heisenberg truly spent much of his life after World War II explaining his actions under the pressure of the Nazi regime. His reputation is still a matter of heated dispute amongst scholars and historians. Frayn offers his characters a final chance, after death, to explain their lives to the world, each other, and themselves. After thirty or more years of explaining, we can imagine that a person would be nearly desperate to have a final say, to offer the full justification of his or her acts, a final judgment formed over years of consideration.

Heisenberg's frustration may parallel any defense Frayn has to put up for his play. "I realize that we must always be conscious of the wider audience our words may have," Bohr says near the beginning of the play. The use of the word audience indicates an awareness on Frayn's part of the parallel between the characters' explanations and the response of his audience. It may easily be Frayn's doom to continually justify his omissions, additions, or interpretations of the events. Such is a
necessary evil when engaging the realms of science, history, and drama. To this end, Frayn includes a postscript explaining not only his own research, but the varying theories of modern physics and historical studies of Heisenberg’s life.

We have already seen how mathematics fails Heisenberg and Bohr as a language. If, even for two versed mathematicians, the language of mathematics falls short, then how do they explain it to the world at large, or even one person like Margrethe? They are required to seek out another method or language of explanation.

At times, however, the mathematics failed because they were never utilized, which may explain why they failed in the case of Heisenberg and the calculation of critical mass. Like any language, mathematics will not work unless put to valuable use. In Heisenberg’s case, the mathematics disappoints him again because he neglected it. And the implication is that, if he had used them, it would have been to terrible effect.

Perhaps the mathematics needs to function as poetic expression, like the phrase “Elsinore.” After Bohr and Heisenberg explain that German treatment of Jewish physicists had forced them into exile and into Allied hands, Heisenberg muses, “There’s something almost mathematically elegant about that.” The math is not utilized as a quantifier or explainer, but as an exprresser.

What Heisenberg, Bohr, and Margrethe find as an adequate language is the movement of bodies in space: in acting it out. Frayn packs Copenhagen full of examples of human action used to illuminate scientific principles. If all we have is ourselves, then we must use ourselves – our bodies – even in demonstrating the life of the world at the atomic level. Stewart, voicing the concerns of Broderick about scientific versus everyday language, notes the difficulty in denoting these moments as
either the author using scientific metaphor or the scientist using everyday language to explain scientific principle. To use complementarity momentarily, I would argue that both are possibilities, and even necessities. I would even consider the moments as examples when the scientist demonstrates his theories in “plain language.” Heisenberg, Bohr, and Margrethe could be seen as attempting several thought experiments.

Heisenberg himself first grasped uncertainty when he thought about the particles in terms of human movement. As he strolled around Faelled Park in Copenhagen one evening, while Bohr was away skiing in Norway, he imagined what Bohr would see of his perambulations. He quickly realized that Bohr would catch only brief glimpses of him as he passed under the streetlamps, and could then only estimate Heisenberg’s course and speed. Likening his stroll to the trajectory of an atom, Heisenberg discovered a language capable of unlocking the theory that would revolutionize modern science.

He quickly adds another example using a person’s movement: Bohr’s “papal progress” by train across Germany and the Netherlands. Margrethe, Heisenberg explains, could only deduce her husband’s route by the periodic postcards she received, whose postmarks would give her a city, perhaps a date, and nothing more. She had to judge his position only by external effects, small “collisions” that resulted in a mailing back home.

But what is most profound about Frayn’s enactment of science on stage is that his characters turn toward performance as a last resort. All other languages – verbal, mathematical, poetic – have proved futile or incomplete, forcing them to rely on a language of performance. Heisenberg relies on acting out the principle in another
moment of exhaustion with Bohr. Suddenly, it seems, Heisenberg’s faith in the
language of science wavers, and he must imitate the science for Margrethe:

BOHR. And the uncertainty arises not, as you claim, through [an electron’s]
indeterminate recoil when it’s hit by an incoming photon. . . .
HEISENBERG. Plain language, plain language!
BOHR. This is plain language.
HEISENBERG. Listen. . . .
BOHR. The language of classical mechanics.
HEISENBERG. Listen! Copenhagen is an atom. Margrethe is its nucleus. About
right, the scale? Ten thousand to one?  

Heisenberg’s repetition of “Listen!” implies his struggle to keep Bohr’s attention or
convince him. Tension rises as the language and the mathematics fail, forcing
Heisenberg to once again act out the concept using human bodies. He continues by
sending Bohr into orbit as an electron prowling about Copenhagen while Heisenberg, as
a photon of light, journeys through the darkness and eventually collides with Bohr. The
collision of the actors’ bodies (assuming the director blocks a degree of physical
contact) demonstrates accurately the effect of two separate molecules meeting head-on
and being redirected by the collision.

Stewart draws a very interesting comparison in which acting out the science
goes beyond exhaustion and becomes a desperate matter of life or death. Heisenberg’s
story of his encounter with the SS man points up “the notion that the presence of mind
activated in such an incident is comparable to that in which Heisenberg achieved
scientific breakthroughs.”  

Heisenberg likens that moment, when he offered the
cigarettes as payment for his life, to his skiing excursions or the night on Heligoland
when he discovered the uncertainty principle. Heisenberg’s genius comes to fruition,
Stewart says, when he enacts his scientific thinking in everyday life.
Margrethe, too, provides one of the most lucid explanations of Bohr’s complementarity principle in the plainest language, once again using human action as the example. “If you’re doing something you have to concentrate on you can’t also be thinking about doing it, and if you’re thinking about doing it then you can’t actually be doing it.”

Looking at one thing necessarily neglects the other, she says, and you get what you look for. She expresses this, very succinctly, using motion as the example.

The characters best demonstrate the necessity of performance in the third and final “draft” of the 1941 meeting, wherein they walk themselves through the meeting once more, this time in the most considered and deliberate fashion. The characters narrate their way through the draft, describing their particular point of view as the scene unfolds. The action is the polite conversation of a friend coming to dinner, yet they infuse it with exhibitions of uncertainty and complementarity. The demonstration begins as Heisenberg, confident in his motivation for coming, loses all certainty when the moment comes to explain himself:

BOHR. Until this instant his thoughts have been everywhere and nowhere, like unobserved particles, through all the slits in the diffraction grating simultaneously. Now they have to be observed and specified.

HEISENBERG. And at once the clear purposes inside my head lose all definite shape. The light falls on them and they scatter.

Immediately the characters launch into the meeting as they have before, this time voicing aloud explanations for their actions. “How difficult it is to see even what’s in front of one’s eyes,” Heisenberg discerns as he watches Margrethe slip from view when he turns to Bohr, “And yet how much more difficult still it is to catch the slightest glimpse of what’s behind one’s eyes.” The observer affects the events as they unfold in applying his or her interpretation, and yet is unable to view him or herself except by
glimpses of the external effects he or she produces: Bohr seeing in Margrethe his own
smile fade as Heisenberg blunders through awkward conversation, or Heisenberg
observing his hosts' reactions to his presence. All the while, one must recall
Margrethe's expression that one cannot do something and think about doing it
simultaneously. So the characters could be said to not be doing the action, since they are
thinking about doing it.

The results of this final draft express an important point about know-ability,
historiography, and otherwise; namely, should everything be known? There is a tone of
celebration in the moments following the realization in which Margrethe offers that that
meeting was the "greatest demand" Heisenberg could have asked of Bohr, to "leave him
misunderstood." This is something of an argument for subjectivity and unknow-
ability. If, in this famous meeting, Bohr and Heisenberg had acted perfectly rationally
and objectively, quite opposite to typical human nature, perhaps it would have produced
the worse result of Heisenberg building an atomic bomb. One might argue that if the
perfectly rational and objective result had occurred, it would subscribe to Newton's
universe of causality. Instead, as quantum physics implies on the scientific and
philosophical level, too many unobservable factors exist in the movement of both atoms
and humans to make the world completely predictable. In short, what would happen if
everything became known? What would become of scholarship and historiography if
every detail could be perfectly known? We might argue, as with the above example
from the play, that the circumstances of life are better because we cannot know
everything. As Bohr replies to Margrethe, when she asks why physicists work on fission despite the belief that it leads nowhere: “Because there’s an element of magic in it.”91 What would become of our world if there were no magic left in it?

The point seems clear within the world of the play that the science benefits greatly from being performed. For how many audience members did these moments finally clarify the scientific elements? As the science elucidates human behavior, that same behavior is returning the favor and illuminating the science. In light of Bohr’s and Heisenberg’s philosophical musings, it is extremely important that everyone be able to understand the science, at least to some degree. If these theories really do reassign the role of man in the scheme of the universe, it should be understandable to all. Physics, the very workings of our world, involves us all on a daily basis.

4.6 CONCLUSIONS

Stewart’s article explores Copenhagen’s creation of a dialogue between the discourses of science and theatre, revealing their respective concerns with ambiguity and uncertainty. One possible reason for Copenhagen’s popularity is its indefinite conclusions. “The method by which [Frayn’s] answers are attempted becomes as compelling as the suggestions themselves,” notes Stewart. “Frayn’s use of Heisenberg’s principle of uncertainty ultimately reveals that this plurality of possibilities has to replace any search for a definitive answer.”92

And that is where Frayn leaves us. Not with the danger of moral reasoning that could justify any action, but with the need to accept a “plurality of possibilities” rather than a definitive answer from ourselves. Our past and its conditions add up to our
present, and we observe our past through the knowledge of the present, which
reassembles, reemphasizes, and reinterprets the details. We will never forget the past,
nor will we completely understand it.

So how does Copenhagen stand against various objections and warnings about
science in literature? I have already addressed how Frayn defeats Cargill’s warnings
about transient theories and language; rather than using contemporary models, Frayn
reaches back into history, actually using century-old science. If Frayn is open to any
criticism, I think it would mainly be his use of uncertainty and complementarity as
metaphors. Although I believe he applies them with reservation, and with the
understanding of their limits, he neglects to clarify that uncertainty applies at the
smallest levels, while Newton’s laws still affect life on the human level. While
Heisenberg refers to microscopic measurement, none of the characters actually explain
the limits of uncertainty and the difference between the small and the large.

Copenhagen will most likely not be the last effort to sort out the story of Bohr
and Heisenberg (nor did Frayn intend it to be); it offers another draft in understanding,
using a specific language to articulate the difficulties of observing ourselves and our
context in the world. Perhaps history (or individuals within it) can still turn judgment on
Heisenberg, Bohr, and their colleagues, but we are forever denied the details, leaving at
the heart of the issue, as Heisenberg says, “that final core of uncertainty.”\(^9^3\)
1 One at the Niels Bohr Institute in Copenhagen, for instance, in February 2002. Also in New York in March 2000 and Columbus, OH on February 10, 2004. For an extensive listing, see CUNY Graduate Center New Media Lab, <http://web.gc.cuny.edu/sciart/index.htm>.

2 See Copenhagen in Theatre Record 18.2 (21 May-3 June 1998): 707-713.


4 Frayn, Constructions 283, 88.


6 Frayn, Copenhagen 54.

7 Frayn, Copenhagen 84. Although Frayn includes no specific stage directions regarding this moment, directors of the London, New York, and Columbus productions — as well as many others — inserted the simulation by sound and light of a nuclear explosion, usually while the characters stared into the audience or generally paused on stage. This served well to emphasize the gravity of these moments. Historically it might be difficult to say whether this would have been the case; many historians agree that although the technical skill existed in the German atomic program, there seemed to be a lack of zeal, especially when compared to that of the Manhattan Project team at Los Alamos. However, Bohr accurately remarks in the play that as of June 1942, Heisenberg and his team were slightly ahead of Enrico Fermi’s parallel experimentation in Chicago.

8 Frayn, Copenhagen 99.


10 Frayn, Copenhagen 88.

11 Frayn, Copenhagen 38.

12 Frayn, Copenhagen 75.

13 Frayn, Copenhagen 60.

14 Frayn, Copenhagen 47.


16 Frayn, Copenhagen 59.

17 Frayn, Copenhagen 67.

18 Frayn, Copenhagen 25.

19 Frayn, Copenhagen 25.

20 Frayn, Copenhagen 24.

21 Frayn, Copenhagen 25-6.
Frayn, *Copenhagen* 3.

Frayn, *Copenhagen* 4.

Frayn, *Copenhagen* 5, 58.

Frayn, *Copenhagen* 29.

Frayn, *Copenhagen* 20.

Frayn, *Copenhagen* 99.

Frayn, *Copenhagen* 97.

Frayn, *Copenhagen* 29.

Frayn, *Copenhagen* 77-8.

Frayn, *Copenhagen* 75.


Frayn, *Copenhagen* 37.

Frayn, *Copenhagen* 86.

Frayn, *Copenhagen* 30-1.

Frayn, *Copenhagen* 57-8.

Frayn, *Copenhagen* 76.

Frayn, *Copenhagen* 8.

Frayn, *Copenhagen* 29.

Frayn, *Copenhagen* 65.

Frayn, *Copenhagen* 23.

See Pais and Frayn.


Frayn, *Copenhagen* 26-8.

Frayn, *Copenhagen* 7.

Frayn, *Copenhagen* 256.

Frayn, *Copenhagen* 73.
48 Frayn, *Copenhagen* 50.
49 Frayn, *Copenhagen* 52.
50 Frayn, *Copenhagen* 68.
52 Frayn, *Copenhagen* 64-5, 71.
54 Frayn, *Copenhagen* 69.
55 Frayn, *Copenhagen* 69.
56 “Creating Copenhagen” 4.
57 “Creating Copenhagen” 6-7.
58 Frayn, *Copenhagen* 92.
59 Frayn, *Copenhagen* 92.

62 Frayn, *Copenhagen* 23.
63 See Pais and Frayn.
64 Frayn, *Copenhagen* 70.
67 See Frayn’s postscript to the play for a good summary of the argument.
68 Frayn, *Copenhagen* 72.
69 “Creating Copenhagen” 7.
70 Frayn, *Copenhagen* 35.
71 Frayn, *Copenhagen* 72.
72 Frayn, *Copenhagen* 78.
73 Frayn, *Copenhagen* 31.
74 Frayn, *Copenhagen* 38.

75 Frayn, *Copenhagen* 80.


77 "Creating Copenhagen" 2.

78 Stewart 303.

79 Frayn, *Copenhagen* 17, 47.

80 See Logan and Rose.

81 Frayn, *Copenhagen* 17.

82 Frayn, *Copenhagen* 83.

83 Stewart 302.

84 Frayn, *Copenhagen* 67,

85 Frayn, *Copenhagen* 68.

86 Stewart 306.

87 Frayn, *Copenhagen* 72.

88 Frayn, *Copenhagen* 86.

89 Frayn, *Copenhagen* 86.

90 Frayn, *Copenhagen* 89.

91 Frayn, *Copenhagen* 12.

92 Stewart 303.

93 Frayn, *Copenhagen* 94.
CHAPTER 5

CONCLUSION

5.1 TOWARDS THE THIRD CULTURE

As _Copenhagen_ and all of the plays discussed demonstrate, the relationship between science and drama can thrive with electrifying results. While fears still linger about the disparity between the two fields, they grow closer together every year through the efforts of scientists, playwrights, and practitioners. The key, it seems, is finding a common language. Already in 1966 Karl Weimar saw writers and scientists finding a common language in their increased use of metaphor.¹ They have expanded their tools today to include metaphors, scientific language, even music.

Science and drama both concern themselves with telling the truth, no matter how difficult or uncertain it may be and, as such, they have an obligation to each other. Ultimately, both utilize the form of an experiment, the subjects of which are human beings. The responsibility is to tell the truth about each other and about human beings. Most importantly, this duty between science and drama comes with several benefits.
5.2 MUTUAL BENEFITS

The benefits between science and theatre are mutual. Despite objections from scientists that the science may be applied at the “pop level,” one can easily argue that it is better at the pop level than not at all.² Not everyone can be expected to understand science as much as the scientists. Many reviewers of science plays begin by noting the general public’s fear or misunderstanding of science, after all.³ After playwrights and scientists find their shared language, it is possible that they may share this language with audiences, and establish a better understanding of both, perhaps allaying any fears or difficulties with science. Playwrights indeed have shown us that it can happen: Galileo, after all, writes his Discorsi in Italian as opposed to Latin.

The science will always appear on the pop level to the specialist, and while drama must be ready to accept the responsibility of representing the science correctly, scientists must be ready to accept that the playwright’s obligation to tell the story effectively, even if that means altering details. As Frayn demonstrates in Copenhagen – through the term Elsinore – definitive human expression (even if an expression of uncertainty) must come through the imagination and poetic representation. A number of scientists and historians take issue when Frayn and other writers step into their territory, and understandably so, but to expect a playwright to include every detail and know every fact, and not make it artful, is unrealistic. Paul Lawrence Rose, in his criticism of Copenhagen, criticizes Frayn for his “poetic license.”⁴ Yet if Frayn did not take some poetic license, he might instead create a dull, uninspiring play which misrepresents Bohr’s, Margrethe’s, and Heisenberg’s personalities and history.
The use of science in drama demonstrates the ability of theatre to teach an audience, even if it only offers the first step of inspiring an audience to learn more. A particular fascination of mine has always been the interdisciplinarity of the arts, sciences, and humanities, and especially how the arts have taught me more about science and history than I can remember learning in grade school (which might just say something about my abilities as a student). Recent favorite new plays are Shared Experience’s *After Mrs. Rochester*, in which I learned about the life of writer Jean Rhys, the novel *Jane Eyre*, and the history of England and the Canary Islands. Others include *Copenhagen*, were I first grasped physics beyond momentum, levels, and pulleys, and Frayn’s *Democracy*, where I learned about German history in the 1960’s and 70’s, leading up to the fall of the Berlin Wall. Also of note is Antony Sher’s *I.D.*, which taught the history of South Africa, Hendrik Vanwoerd, the architect of apartheid, and his assassin, Demetrios Tsafendas. All true stories and knowledge about the world, all learned when brought to life on stage.

Theatre also exemplifies science’s ability to uncover truths about the world. Paul Rae, in a review of *Proof*, notes that science playsmeasure how science describes human beings:

These are not simply plays about scientists, but about science, in the sense that they seek not only to describe scientific phenomena, but to measure their truth claims and implications against the personal and human realities theatre excels in dramatizing, and to enact them in the staging of the theatrical event itself.¹ Theatre reveals, Rae indicates, that science does not happen in a vacuum. It must be explained to the wider world, and in doing so gets tangled in politics and interpretation. Frayn suggests that Heisenberg mistakenly believed that physics could seal itself away
from politics. Lee Riedinger's comment about the difficulty of the hand-off exemplifies this belief. Scientists, he said, are logical and therefore naïve. While not implying the ignorance of scientists, he noted that they do not always consider the political squabbling and selfish gain possible from scientific advance. Since the practice of science and application of its theories remain connected with the world at large, it should be art's (specifically drama's) duty to engage the discipline, to open it up to common human understanding, to explore its implications and how it shapes the future of the human race.

Drama benefits from science in that it discovers new and exciting topics. Just as science is continually changing, and what we once thought impossible becomes possible, so too does the subject of drama. More than one scholar predicted that atomic physics could never make a good artistic subject. "It is probably safe to cite the discovery of atomic power in a novel," stated Cargill in 1951, "but to make the action wholly dependent upon its use is poor literary strategy and probably bad science." Weimar agreed years later: "Such formidable complexity hardly lends itself to dramatic treatment." Plays like Copenhagen have proven that the possibility not only exists, but can awaken and expand interest in understanding science as science cannot do itself.

The final benefit comes from an earlier line by Frayn's rendering of Bohr. When Margrethe questions why scientists chase after fission's use as a weapon despite Bohr's pronouncement otherwise, he replies, "Because there's an element of magic in it." The number of science plays has undoubtedly grown even during the span of this writing, and while drama and science carry on growing, the two disciplines will turn to each other for help in continuing to create this magic.


8 Weimar 433.

## APPENDIX

### A LIST OF PLAYS INVOLVING SCIENCE
(WITH A FOCUS ON PHYSICS, ASTRONOMY, CHEMISTRY, MATHEMATICS, BIOLOGY, AND MEDICINE)

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Author</th>
<th>Country</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1604</td>
<td><em>Dr. Faustus</em></td>
<td>Christopher Marlowe</td>
<td>Britain</td>
<td>pursuit of knowledge</td>
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<tr>
<td>1610</td>
<td><em>The Alchemist</em></td>
<td>Ben Jonson</td>
<td>Britain</td>
<td>alchemy</td>
</tr>
<tr>
<td>1808/32</td>
<td><em>Faust</em></td>
<td>Goethe</td>
<td>Germany</td>
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<tr>
<td>1836</td>
<td><em>Woyzeck</em></td>
<td>Frederick Bächner</td>
<td>Germany</td>
<td>experimentation, anatomy</td>
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<tr>
<td>1882</td>
<td><em>An Enemy of the People</em></td>
<td>Henrik Ibsen</td>
<td>Norway</td>
<td>medicine, public health</td>
</tr>
<tr>
<td>1889</td>
<td><em>Before Daybreak</em></td>
<td>Gerhart Hauptmann</td>
<td>Germany</td>
<td>scientific method, genetics</td>
</tr>
<tr>
<td>1899</td>
<td><em>The Physician</em></td>
<td>Henry Arthur Jones</td>
<td>Britain</td>
<td>medical practice</td>
</tr>
<tr>
<td>1906</td>
<td><em>The Doctor's Dilemma</em></td>
<td>George Bernard Shaw</td>
<td>Britain</td>
<td>medical practice</td>
</tr>
<tr>
<td>1921</td>
<td><em>R.U.R.</em></td>
<td>Karel Capek</td>
<td>Czechoslovakia</td>
<td>robotics</td>
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<td>1933</td>
<td><em>Men in White</em></td>
<td>Sidney Kingsley</td>
<td>United States</td>
<td>medicine</td>
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<tr>
<td>1948</td>
<td><em>E=mc²</em></td>
<td>Hallie Flanagan Davis</td>
<td>United States</td>
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1984  *Einstein*  Gabriel Emanuel  Canada  Einstein
1986  *No Mercy*  Constance Congdon  United States  first atom bomb
1988  *Hapgood*  Tom Stoppard  Britain  quantum mechanics
1993  *Arcadia*  Tom Stoppard  Britain  chaos theory
1994  *Molly Sweeney*  Brian Friel  Ireland  visual impairment
1996  *Blinded by the Sun*  Stephen Poliakov  Britain  biology
1996  *Einstein, A Stage Portrait*  Willard Simms  United States  Einstein
1996  *Picasso at the Lapin Agile*  Steve Martin  United States  Einstein
1998  *After Darwin*  Timberlake Wertenbaker  Australia  Darwinism
1998  *Great Men of Science, nos. 21 and 22, or Our Great Labors at The Empty Space*  Glen Berger  United States  scientific method
1998  *Copenhagen*  Michael Frayn  Britain  quantum physics
1998  *Flight*  Arthur Giron  United States  aviation
1999  *The Idiot*  Paul Jepson  Britain  epilepsy
1999  *Greenland Y2K*  Melissa Klievan  United States  string theory, polar exploration
1999  *The Lone Runner*  Jane Catherine Shaw  United States  Nikola Tesla
1999  *Moving Bodies*  Arthur Giron  United States  Richard Feynman
1999  *Safe Delivery*  Tom McGrath  Scotland  gene therapy
1999  *The Secret Order*  Bob Clyman  United States  biology, Nobel Prize
1999  *Tesla's Letters*  Jeffrey Stanley  United States  electrical engineering
1999  *W;f*  Margaret Edison  United States  oncology
1999  *Y2K*  Arthur Kopit  United States  computer hacking
2000  *The Automata Pieta*  Constance Congdon  United States  complexity theory
2000  *The Einstein Project*  Paul D'Andrea and Jon Klein  United States  Einstein
2000  *An Experiment With An Air Pump*  Shelagh Stephenson  Britain  genetics, experimentation
2000  *Fermat’s Last Tango*  Joanne Sydney Lessner and Joshua Rosenbaum  United States  Fermat
2000  *The Five Hysterical Girls Theorem*  Rinne Groff  United States  prime numbers
2000  *Hypatia, or The Divine Algebra*  Mac Wellman  United States  algebra, astronomy
2000  *Imperfect Chemistry*  Albert M. Tapper and United States  science ethics
2000  *Mnemonic*  James Rachell  James Rachell  memory, ice man
2000  *One Day Earlier*  Constance Congdon  United States  Einstein, Meitner
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<td>Mark Medoff</td>
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<td>2004</td>
<td><em>Tooth and Claw</em></td>
<td>Michael Hollinger</td>
<td>United States</td>
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