A reprint from

American Scientist

the magazine of Sigma Xi, The Scientific Research Society

Science as Theater

From physics to biology, science is offering playwrights innovative ways of exploring the intersections of science, history, art and modern life

Harry Lustig and Kirsten Shepherd-Barr

> Two thousand million people in the world,
> and the one who has to decide their fate is the
> only one who's always hidden from me…..

On a bare stage, actor Hank Stratton, playing the role of Werner Heisenberg in Michael Frayn's acclaimed play Copenhagen, muses on the impossibility of self-knowledge. The fictional Heisenberg is agonizing over his role in the Nazi effort to build an atomic bomb and finds himself unsure of his own motivations.

For four years on the London stage, two years on Broadway, and in cities across Europe and America, Copenhagen has defied the conventional wisdom that science and art cannot co-exist. Despite or perhaps because of its heady mix of quantum physics and moral dilemmas, it has been popular with critics and audiences alike; it won the Tony Award for Best New Play in 2000 and was filmed for presentation this fall to U.S. public-television audiences. As New York Times critic Ben Brantley put it, "Who would have ever thought that three dead, long-winded people talking about atomic physics would be such electrifying companions?"

Yet the success of Copenhagen has not been an isolated phenomenon. In recent years, science has become a surprisingly popular subject for playwrights. According to our best count, more than 20 plays on a scientific theme have opened in a professional production over the last five years, although none has yet matched Copenhagen's popular success. At the very least, science is in vogue on stage as it has never been before. The best of these plays go far beyond using science as an ornament or a plot device. They seriously embrace scientific ideas and grapple with their implications. In an era when traditional dramatic subjects such as dysfunctional families have become tired, playwrights have found the lives and discoveries of real scientists to be full of dramatic possibilities and thought-provoking metaphors.

In his famous 1959 essay on "the two cultures," C. P. Snow lamented the widening gulf between science on one side and the arts and humanities on the other, and expressed his hope for a "third culture" of art that would "be on speaking terms with the scientific one." A number of recent science plays show how effective this conversation can be, and suggest that the "third culture" that Snow envisioned may actually be arriving in the intersection between science and the theater.

Anxiety and Distrust

"Science plays" have a long history and a distinguished provenance, starting with Christopher Marlowe's Dr. Faustus, published in 1604. Although it does not deal with specific scientific concepts, the play features a scientist who strikes a bargain with the Devil and meets a horrible demise as a result of his lust for knowledge.

Marlowe's distrust of the motives of scientists set the tone for many future plays in the genre. Other playwrights expressed this distrust in more comedic form. Ben Jonson's The Alchemist (1610) lampooned both the practitioners of this ancient pseudo-science, unmasked by Jonson as jargon-babbling rogues, and their willing dupes. When Jonson's sly alchemist, Subtle, quizzes his accomplice, Face, Jonson has great fun with the terminology of Renaissance science:

> Subtle. Name the vexations, and the
> martyrisations
> Of metals, in the work.
>
> Face. Sir, putrefaction,
> Solution, ablution, sublimation,
> Cohobation, calcinations,
> ceration and
> Fixation.
>
> Subtle. This is heathen Greek,
> to you, now?
> And when comes vivification?
>
> Face. After mortification.

Later, George Bernard Shaw's The Doctor's Dilemma (1906) made fun of a passel of medical charlatans with such famous lines as "Stimulate the phagocytes!" But the play also shows

Harry Lustig is an emeritus professor of physics and Provost Emeritus at City College of the City University of New York. His Ph.D. is in theoretical nuclear physics, and his research ranges from the theory of nuclear reactions to the history of physics. Between 2000 and 2002, with Brian B. Schwartz, he organized and produced three symposia on the play Copenhagen in New York City, Washington and Albuquerque, New Mexico. This article is based in part on a talk he gave at the 2002 Annual Meeting of the American Physical Society. Kirsten Shepherd-Barr is an associate professor of English at North Carolina State University in Raleigh, specializing in modern drama and theater history. She co-organized a Raleigh symposium on Copenhagen in March, organized a "Science on Stage" panel at the 2001 Sigma Xi Forum and is currently on leave in England writing a book about science and theater. Address for Lustig: 304 Chula Vista Street, Santa Fe, NM 87501. Internet: lustig@aps.org. For Shepherd-Barr: Department of English, Box 8105, NCSU, Raleigh, NC 27695-8105. Internet: ksbarr@unity.ncsu.edu

Figure 1. Michael Frayn's Copenhagen has been the bellwether of a flock of new science plays in recent years. In this publicity photograph from the touring production, Hank Stratton (center) as Werner Heisenberg addresses Len Cariou (right) as Niels Bohr, while Mariette Hartley (left) as Margrethe Bohr listens. In actual performances, spectators have occupied the stalls behind the actors, creating the impression of a tribunal. (Photograph by Joan Marcus, courtesy of Broadway in Boston / Clear Channel Entertainment.)

that Shaw has genuinely investigated the biochemistry that the doctors discuss.

Bertolt Brecht's Galileo, with its portrayal of actual scientists in historical situations, marked a turning point in the history of scientific plays. In a version of the play published in 1939 (but not translated, and therefore not widely known), Brecht took a very positive view of his protagonist; but in later revisions, which were strongly influenced by Hiroshima and Nagasaki, he portrayed Galileo as an antihero. The revised play, published in 1947, is the Brecht Galileo most widely used and read around the world.

Several other playwrights also saw the bomb in Faustian terms. Friedrich Dürrenmatt, in The Physicists (1962), warned of the apocalyptic results of modern physics put into the wrong hands. The play uses the Möbius strip as a central image and is one of the first modern plays to integrate science formally as well as thematically. Another remarkable science play that warns of the dangerous potential of physics, while actually discussing scientific ideas, is Hallie Flanagan Davis's $E = mc^2$ (1948). This play is part allegory and part documentary, as it features a character called Atom and a Professor who explains the physics that the audience needs to know. Much of the play's dialogue is taken directly from transcripts of hearings of the Atomic Energy Commission and contemporary news sources. Davis leaves the fate of the Earth in the audience's hands, pleading with us to choose the right path in our use of atomic energy.

Memory and Duality

Even as they retain some elements of skepticism toward science, contemporary science plays explore a broader range of attitudes and, as in $E = mc^2$, have frequently drawn their themes from science itself. No play illustrates this better than the masterpiece of the genre, Copenhagen.

Michael Frayn's play, familiar by now to many American Scientist readers, re-enacts the 1941 visit of Werner Heisenberg to his mentor and friend Niels Bohr, in Nazi-occupied Denmark. The third "long-winded" character is Bohr's wife Margrethe, who in this play (although probably not in reality) was present for the first part of the conversation. The action takes place outside chronological time, as the three deceased characters struggle, with the hindsight of 60 years of history, to make sense of what happened that afternoon.

From 1939 until Germany's defeat in 1945, Heisenberg was in charge of the most important part of the country's uranium project. As a result of the visit to Copenhagen, the friendship

Science on Stage

Contemporary Plays

After Darwin (1998)
Timberlake Wertenbaker

Arcadia (1993), Galileo (1970, unpublished), Hapgood (1988)
Tom Stoppard

Blinded by the Sun (1996)
Stephen Poliakoff

Calabi Yau (2002)
Susanna Speier

Copenhagen (1998; 2000)
(Also a PBS Hollywood Presents film.)
Michael Frayn

The Division of Memory (2001)
Clarinda Mac Low, James Hannaham and Tanya Barfield

Figure 2. Heisenberg (left) and Bohr chat at a conference in Copenhagen in 1936. The father-son relationship between Bohr and Heisenberg is a central theme of the play Copenhagen. In 1941 Heisenberg, by then the leading scientist in Germany's nuclear program, paid a mysterious visit to Bohr in Nazi-occupied Copenhagen. The friendship between the two men cooled as a result of this visit. The rift was never fully healed, and in later years the two men could not even agree on what had provoked it. (Photograph courtesy of the Emilio Segré Visual Archive, American Institute of Physics.)

An Experiment with an Air Pump (1999)
Shelagh Stevenson

Great Men of Science, nos. 21 and 22 (1998)
Glen Berger

Humble Boy (2002)
Charlotte Jones

An Immaculate Misconception (2001)
Carl Djerassi

Louis Slotin Sonata (2001)*
Paul Mullin

Mnemonic (2000)
Théâtre de Complicité

Molly Sweeney (1994)
Brian Friel

Moving Bodies (1999–2000)*
Arthur Giron

Oxygen (2000)
Carl Djerassi and Roald Hoffmann

Picasso at the Lapin Agile (1996)
Steve Martin

between the two men cooled abruptly. Something had happened, but neither ever explained definitively what it was. Frayn explores the mystery with three alternative scenarios, or "drafts" as the characters call them, each with different outcomes. No concrete answers are provided in the text. Even the characters' own memories of the events prove unreliable.

The questions begin with the very opening lines from Margrethe to her husband: "Why did he [Heisenberg] come to Copenhagen? … What was he trying to tell you?" They continue: Did Heisenberg say to Bohr what he had intended? If not, why not? What was Bohr's reaction? What was Heisenberg's? And inevitably, why did the Germans not achieve an atomic bomb, and why, under Heisenberg, did they not even try—or did they? Did Heisenberg deliberately slow down the bomb effort for moral reasons? Was it Heisenberg's or his fellow German scientists' incompetence? Had he made an incorrect calculation, or no calculation at all, of the critical mass required for an explosive chain reaction?

In the script, Frayn dives right into the physics, going far beyond what most theatergoers can be expected to know. The level of sophistication makes the characters believable, and it also conveys crucial plot points. First, the characters explain why they both thought, in 1939, that an atomic bomb could never be produced:

> Bohr. What all this means is that an explosive reaction will never occur in natural uranium. To make an explosion you will have to separate pure [uranium-]235. And to make the chain long enough for a large explosion…
>
> Heisenberg. Eighty generations, let's say…
>
> Bohr. … you would need many tons of it. And it's extremely difficult to separate.
>
> Heisenberg. Tantalisingly difficult.
>
> Bohr. Mercifully difficult. The best estimates, when I was in America in 1939, were that to produce even one gram of U-235 would take 26,000 years. By which time, surely, this war will be over.

Later we find out what they had missed:

> Heisenberg. Because you'd always been confident that weapons would need 235 and that we could never separate enough of it. […]
>
> Heisenberg. What we'd realised, though, was that if we could once get the reactor going…
>
> Bohr. The 238 in the natural uranium would absorb the fast neutrons…
>
> Heisenberg. […] And would be transformed by them into a new element altogether.
>
> Bohr. Neptunium. Which would decay in its turn into another new element…
>
> Heisenberg. At least as fissile as the 235 that we couldn't separate…
>
> Margrethe. Plutonium.
>
> Heisenberg. Plutonium.
>
> Heisenberg. […] If we could build a reactor we could build bombs. That's what had brought me to Copenhagen.

Scientifically, the first passage is not completely accurate, but it is basically correct about what Bohr and Heisenberg had thought at one time. The second passage is scientifically correct, and moreover it is thematically crucial. Heisenberg says he wanted to ask if it was morally right to go on working on the reactor project in light of this apocalyptic discovery; Bohr thinks Heisenberg came to ask for his blessing—or, even worse, for his help.

Copenhagen is built out of such dual, and dueling, interpretations. The title itself does double duty, as the location of the action but also as the name of the famous "Copenhagen interpretation" of quantum mechanics developed by Bohr and Heisenberg in the mid-1920s. In this interpretation, the state of a quantum particle is not determined until the act of observation puts it into a definite state. Even then, complementary attributes such as a particle's position and momentum obey an uncertainty relation: The more precisely the observer (who may be a machine)

measures one, the less precisely can the other be measured. Quantum-mechanical objects and light behave, to use classical language, sometimes as waves and sometimes as particles. The principle of complementarity states that these two attributes can never be demonstrated in the same experiment or observation.

The uncertainty principle and complementarity are grist for the playwright's mill. The characters cannot agree on anything that happened—not even when and where the conversation took place. The staging of the play reinforces the scientific ideas. In the Broadway and London productions, the stage was round and bare, and the actors' motions around it called to mind the electrons, protons and neutrons moving in an atom. Some of the audience sat in a tribunal at the back of the stage, watching and "judging" the action in stark marble stalls. They were in turn watched by the rest of the audience—the observers observed.

Many philosophers of science have questioned the application of the Copenhagen interpretation to the macroscopic world of human beings, finding it impermissibly reductive. In spite of the fact that this extrapolation is the very premise of the play, in one of his two copious "postscripts" Frayn has said he doesn't take it literally. "The concept of uncertainty is one of those scientific notions that has become common coinage, and generalized to the point of losing much of its original meaning," he writes. Clearly his intent is not to debase the coinage any more. Instead, he uses uncertainty as a metaphor (always part of the artist's license) for the inherent unfathomability of memory, "a systematic limitation which cannot even in theory be circumvented."

Copenhagen has, in its own way, created an observer effect, leading to a reexamination of the historical record that it scrutinizes. In February, a decade ahead of their stated schedule, the Bohr family unsealed, for publication, some letters to Heisenberg that Bohr drafted in the 1950s but never sent. They cast serious doubt on one of the suggestions in the play: that Heisenberg might have been reluctant to work on the bomb for moral reasons. But the new revelations do little to settle the uncertainties in the play and nothing to alter Frayn's essential points about uncertainty. In fact, some lines of Bohr's letters, such as his repeated statement "I am greatly amazed to see how much your memory has deceived you," read as if they could have been written by Frayn.

The Slip of the Screwdriver

On May 21, 1946, Louis Slotin, a Canadian physicist at Los Alamos, repeated a "criticality test" that he had done many times before. He slipped the pieces of a plutonium bomb closer together and farther apart, "flirting" (as Dennis Overbye has written in the New York Times) "with the moment when the assembly would be tight enough to achieve critical mass." He had chosen an extraordinarily dangerous partner to flirt with. Richard Feynman once called such experiments "tickling the dragon's tail."

Ordinarily, wooden spacers separated the two halves of the bomb and prevented a chain reaction from getting started. But for the test, Slotin had removed the spacers and was using the blade of a screwdriver to keep the shells apart. The screwdriver slipped, and the assembly clicked together. A blue glow enveloped the room. Slotin pulled the bomb apart instantly, but there was no way to undo the lethal dose of radiation he had received. Seven other men who were in the chamber with him received smaller doses and survived, because they had been shielded by Slotin's body, but he died after nine days of increasing agony at the Los Alamos hospital.

Playwright Paul Mullin has turned this terrible accident into what could be one of the most provocative science plays since Copenhagen, called Louis Slotin Sonata. (Like several other recent science-based dramas, this play received funding from the Alfred P. Sloan Foundation through a program that encourages playwrights and artists to take on scientific and technological themes.) Where Copenhagen is spare and cerebral, Louis Slotin Sonata is flamboyant and emotional. In the play, Slotin suffers hallucinations during his final days, giving Mullin a chance to bring on some unlikely characters. J. Robert Oppenheimer is there, repeating his line from the Bhagavad-Gita: "I am become death, shatterer of worlds." Einstein shows up—you guessed it—playing dice, and God himself puts in an appearance, dressed in a pinstripe suit and fedora and bearing an uncanny resemblance, as Overbye points out, to Harry S. Truman. Obviously the playwright is giving the audience some strong hints about human beings playing God.

In one of the hallucinations, Josef Mengele, the sadistic Nazi death camp doctor, arrives in Hiroshima to watch the scientists achieve in milliseconds "what took us years to do in stinking, filth-filled camps." To critic Bruce Weber, writing in The New York Times, the scene seemed too contrived: "It feels motivated by theatricality rather than drama, especially when Mengele leads the show's weirdest sequence, a parody of a vaudeville chorus line, with scientists singing doggerel about thermodynamics. Like a lot of elements in the play, the scene is ornamental and distracting, presented by the playwright not because he should but because he can."

Louis Slotin Sonata succeeded in provoking a symposium at Los Alamos after a special reading of the play. (The postperformance symposium seems to be turning into a new science / art form; Copenhagen has also given rise to several of them.) Many of the Manhattan Project veterans

Proof (2000)
David Auburn

Q.E.D. (2001)
Peter Parnell

Safe Delivery (1999)
Tom McGrath

Schrödinger's Girlfriend (2002)
Matthew Wells

The Secret Order (1999–2000)*
Bob Clyman

Space (2001)
Tina Landau

Three Tales (2002)
Steve Reich and Beryl Korot

Untitled one-woman show (2000)
Anna Deavere Smith

Wit (1999)
(Also an HBO film.)
Margaret Edson

Y2K (1999)
Arthur Kopit

Late-19th- to mid-20th-century plays

The Doctor's Dilemma (1906)
George Bernard Shaw

$E=mc^2$ (1948)
Hallie Flanagan Davis

An Enemy of the People (1882)
Henrik Ibsen

Galileo (1939; 1947)
Bertolt Brecht

The Genius (1983)
Howard Brenton

In the Matter of J. Robert Oppenheimer (1964; trans. Ruth Speirs and performed 1967–68)
Heinar Kipphardt

Inherit the Wind (1955)
Jerome Lawrence and Robert E. Lee

Men in White (1933)
Sidney Kingsley

The Physicists (1962)
Friedrich Dürrenmatt

R.U.R. (1921)
Karel Capek

Pre-19th-century plays

The Alchemist (1610)
Ben Jonson

Dr. Faustus (1604 and 1616 versions)
Christopher Marlowe

Musicals

Einstein's Dreams (2002), Fermat's Last Tango (2000)
Joanne Sydney Lessner and Joshua Rosenblum

The Electric Sunshine Man (1978)
John F. Wilson and Grace Hawthorne

complained bitterly about the antiscientific bias of the play. But the play's excesses do not hide the fact that Mullin has done his homework; as he told Overbye, he plowed through a three-inch-thick file at Los Alamos on the Slotin case. "I vowed to tell it like it was," he said. "Anything less would be grave digging." It seems to us that the playwright has every right to question whether the atomic scientists were heroes or irresponsible "cowboys," playing around with the dragon when there were safer ways to test the bomb assembly. He is also entitled to the conclusion that the bomb should not have been dropped on Hiroshima and Nagasaki, although one might have wished for a more balanced presentation of the argument.

Still, the "two cultures dichotomy dies hard. Curt Dempster, the artistic director of the Ensemble Studio Theatre, told Overbye after the symposium: "They were running into us, the illusionists. We were running into the reality." Copenhagen has decisively undermined the old argument. Illusion and reality do not have to run into each other, if both are treated with respect.

Evolution and Betrayal

In recent years most "science plays" have been physics plays, perhaps because the bomb brought the consequences of modern physics so forcefully to the public's attention, raising powerful ethical and historical issues that science itself could not solve. But biology has taken its own turn on the stage. One example is Timberlake Wertenbaker's play After Darwin, dramatizing another explosive scientific topic: the theory of natural selection.

After Darwin borrows a metatheatrical technique from Tom Stoppard's mathematics play Arcadia, with scenes alternating between two historical periods. The present-day characters are actors, Tom and Ian, putting on a play about Charles Darwin (played by Tom) and Robert FitzRoy (Ian), the captain of the Beagle. The scenes alternate between this historical costume drama and the present, in which Tom and Ian talk with the Bulgarian director, Millie, and the African-American playwright, Lawrence.

As the play progresses, the tension builds in each time frame. Darwin and FitzRoy become estranged, as the very religious captain feels increasingly threatened by the implications of Darwin's discoveries. FitzRoy even threatens his former friend with a pistol. Ian feels threatened, too, when Tom confides to him that he has been hired to appear in a movie and will have to quit the play in order to do so. That would close down the production. In order to save his job, Ian betrays Tom by secretly e-

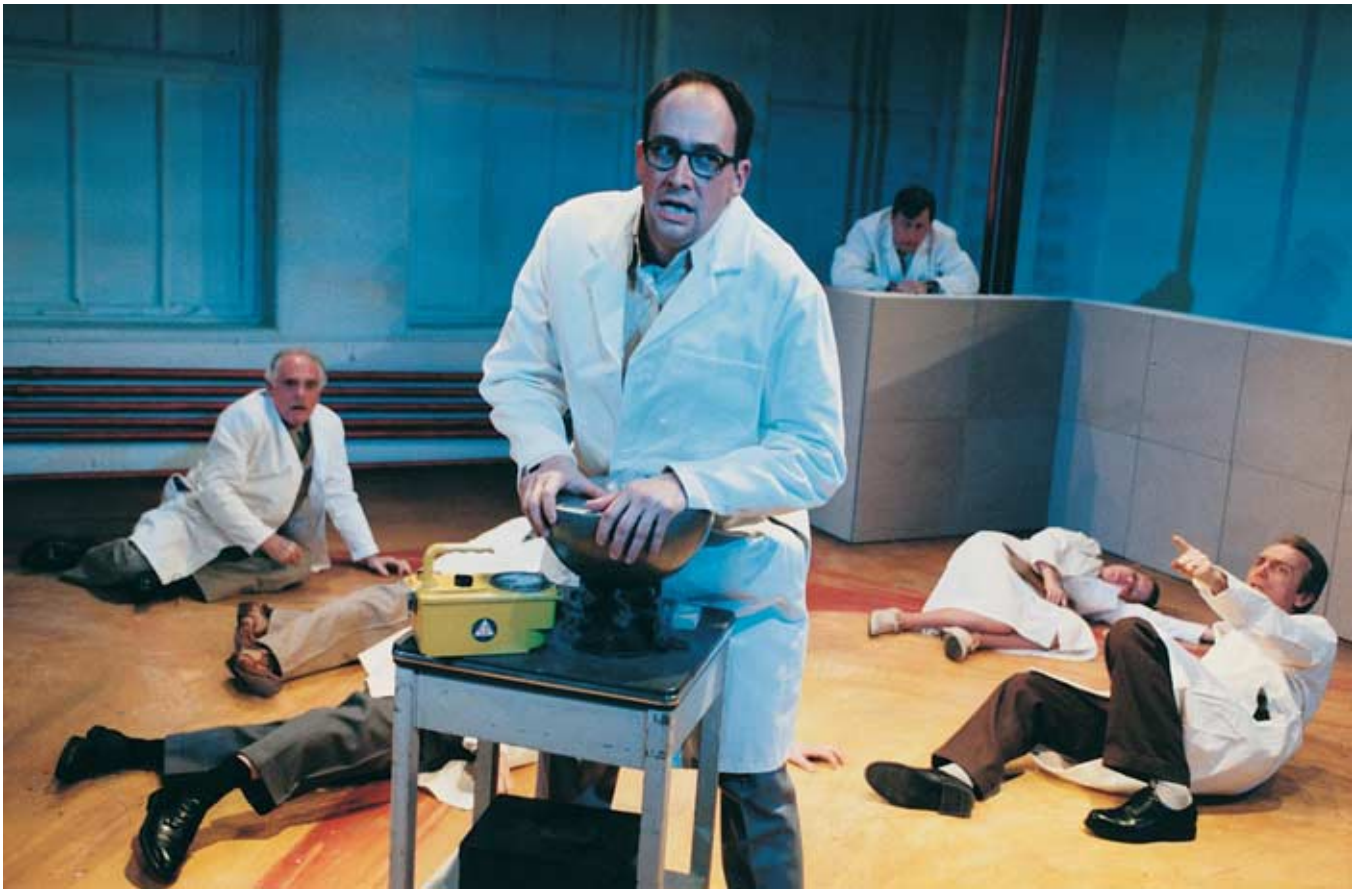

Figure 3. In the Ensemble Studio Theatre's production of Louis Slotin Sonata, Bill Salyers (center) in the role of Slotin clutches the instrument of his demise. The play dramatizes an incident from 1946, when a Canadian physicist working at Los Alamos exposed himself to a lethal dose of radiation while testing the components of a plutonium bomb. (Photograph by Richard Termine for The New York Times.)

mailing the film director and telling him (falsely) that Tom is HIV-positive.

Where does evolution by natural selection come in? Wertenbaker relies on the somewhat shopworn parallel between biological Darwinism and social Darwinism, which seems to be defined here as people being incredibly selfish in order to survive. Tom defends his defection to the film project by citing adaptation and survival, and Ian justifies his betrayal in the same terms: "I don't want another two years without work. I want to survive, I want Millie to survive, I want this to survive." Just as FitzRoy wants his faith to remain intact, Ian wants the play to go on; but both of them know in their hearts that Darwin / Tom's decisions are irrevocable. They object to the way that Darwin and Tom "play God," but they fail to see their own interventions in the same hubristic light.

The play's subplots strengthen the scientific metaphors. The stories of Millie and Lawrence, who are both transplants of a sort, provide different "takes" on adaptation and the losses and compromises it entails. A second subplot involves Ian's "babysitting" a Tamagotchi toy for his niece. The toy is constantly beeping and interrupting him to demand virtual nourishment, which he must provide speedily lest the creature die. The attention he gives to the virtual pet while betraying his flesh-and-blood colleague sends a bleak message about technology as a dehumanizing force.

After Darwin, which was produced at the Hampstead Theater in London, received mixed reviews. On the one hand, the London-based critic Benedict Nightingale noted that Wertenbaker "bangs away at her theme a bit relentlessly." But on the other hand, Nightingale wrote, "the dramatic brew is rich and mentally nourishing, embracing as it does questions of God and godlessness, determinism and free will, biology and ethics." It remains to be seen whether After Darwin presages a lasting subgenre of "biology plays," but it is the first serious attempt to integrate evolutionary theory with the theater both thematically and formally. (As an aside, we would like to note one very worthy successor, Tom McGrath's Safe Delivery, a play about gene therapy inspired by the research of the writer's daughter. This play was sponsored by the Wellcome Trust, which has mounted in England a program comparable to the Sloan Foundation's support of U.S. plays about science.)

We hope that the three plays we have chosen to discuss—out of the many that we could have chosen—give some flavor of the variety of treatments of scientific themes in contemporary plays. The infusion of scientific ideas has invigorated a theatrical scene that, as recently as 15 years ago, was criticized by the prominent theater critic and scholar Martin Esslin for the banality of its subject matter and its refusal to treat topics "outside the narrow range of family squabbles." Clearly, science works as theater. And theater can work at conveying the ideas of science. In an article he prepared for the symposium "The Copenhagen Interpretation: Science and History on Stage," physicist John Marburger wrote, "Many stories can be told of [science's] struggles and their consequences, but I doubt that many will rise to the standard set by Frayn's Copenhagen. I will end by thanking Michael Frayn for bringing the core issues of this beautiful aspect of science to such a large audience." We hope that other playwrights will take up the challenge.

Bibliography

Bernstein, J. 2001. Hitler's Uranium Club, the Secret Recordings of Farm Hall. New York: Copernicus Books.

Bethe, H. A. 2000. The German uranium project. Physics Today 53:34–36.

Bohr, N. 1957–1962. Unsent drafts of letters to Heisenberg and memoranda about the 1941 meeting. Released by the Niels Bohr Archive, February 6, 2002. Naturens Verden 84(8–9); http://www.nbi.dk/NBA/papers/docs/cover.html

Brantley, B. 2000. "Copenhagen": A fiery power in the behavior of particles and humans. The New York Times, April 12:E-1.

Carpenter, C. A. 1999. Dramatists and the Bomb: American and British Playwrights Confront the Nuclear Age, 1945–1964. Westport, Conn.: Greenwood Press.

Cassidy, D. In press. New light on Copenhagen and the German nuclear project. Physics in Perspective.

Frayn, M. 2000. Copenhagen. New York: Anchor Books.

Frayn, M. 2002. Post-postscript. http://web.gc.cuny.edu/ashp/nml/artsci/frayn.htm

Haynes, R. D. 1994. From Faust to Strangelove: Representations of the Scientist in Western Literature. Baltimore: Johns Hopkins University Press.

Jonson, B. 1987. The Alchemist (ed. Peter Bement). London, New York: Methuen.

Logan, J. 2000. "A strange new quantum ethics." American Scientist 88:356–359.

Marburger, J. H., III. 2002. On the Copenhagen interpretation of quantum mechanics. http://web.gc.cuny.edu/ashp/nml/artsci/marburger.htm

Overbye, D. 2001. Theatrical elegy recalls a victim of nuclear age. The New York Times (April 3):F-4.

Pais, A., and M. Frayn. 2000. What happened in Copenhagen? A physicist's view and the playwright's response. Hudson Review 53:2.

Powers, T. 2000. The unanswered question. New York Review of Books, May 25.

Rhodes, R. 1995. The Making of the Atomic Bomb. New York: Touchstone Books.

Rose, P. L. 2000. Frayn's "Copenhagen" plays well at history's expense. The Chronicle of Higher Education (May 5):B4–6.

Ruddick, N. 2001. The search for a quantum ethics: Michael Frayn's "Copenhagen" and other recent British science plays. Journal of the Fantastic in the Arts 11:415-29.

Shepherd-Barr, Kirsten. In press. "Copenhagen" and beyond: The "rich and mentally nourishing" interplay between science and theatre. Gramma.

Snow, C. P. 1993. The Two Cultures. Cambridge, U.K.: Cambridge University Press.

Weber, B. 2001. "Louis Slotin Sonata": A scientist's tragic hubris attains critical mass onstage. The New York Times (April 10):E-1.

Wertenbaker, T. 1998. After Darwin. London: Faber.

Imperfect Chemistry (2000)
Albert M. Tapper and James Racheff

Quark Victory (2000)
Robert and Willie Reale

Star Messengers (2001)
Paul Zimet and Ellen Meadow

(*indicates sponsorship by Alfred P. Sloan Foundation)

An augmented and annotated list of science plays, with capsule summaries and bibliographic information, is available along with links to Internet resources for further exploration of "Science as Theater" on the American Scientist Web site:

http://www.americanscientist.org/articles/02articles/lustig.html