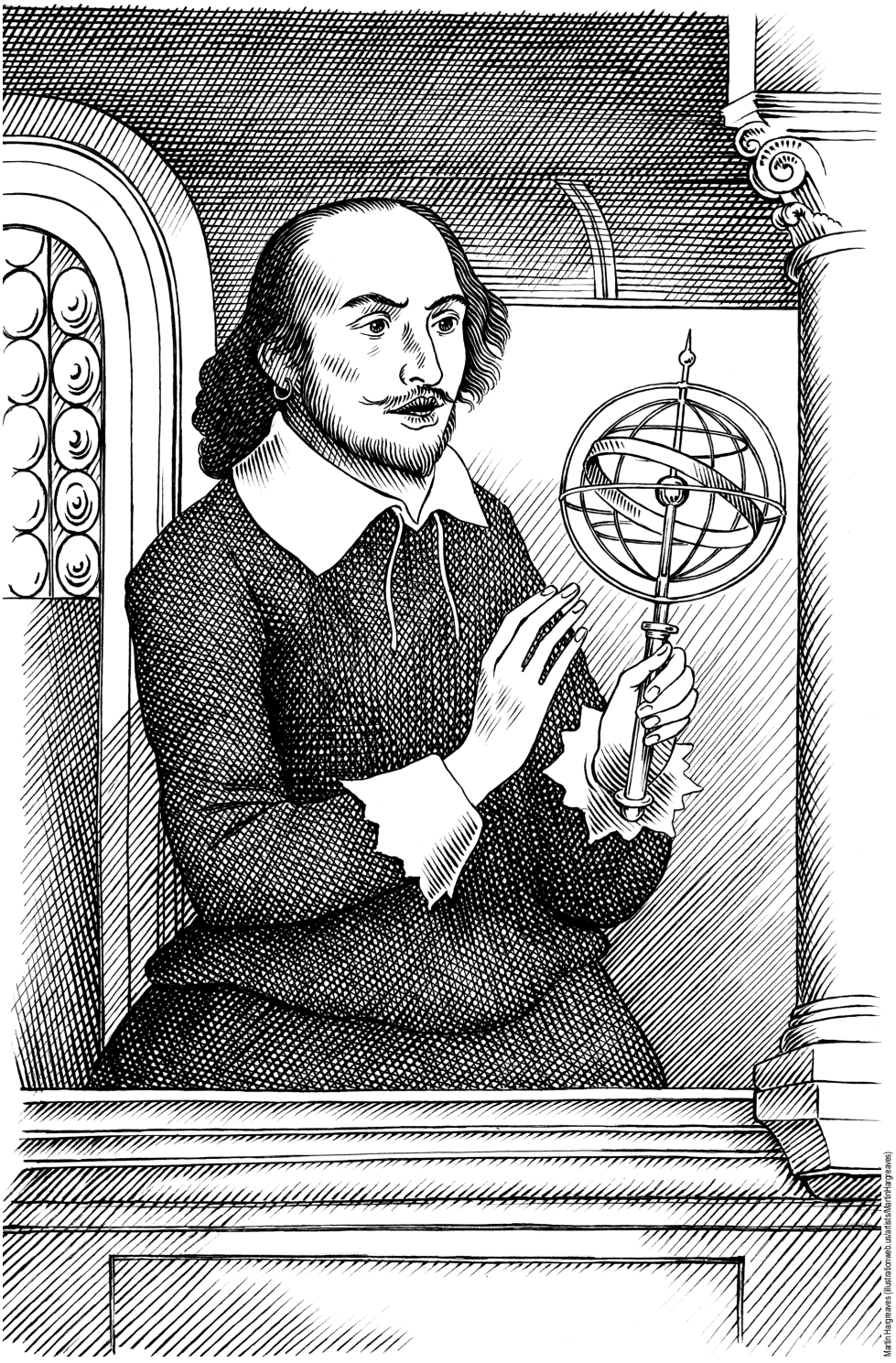

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Shakespeare's Worlds of Science

Natalie Elliot

In Act V of *Hamlet*, after Hamlet has killed Polonius, Ophelia has died, and Hamlet has returned to Denmark from his murderous trip to England, he happens upon two gravediggers. It is an odd and puzzling scene, and a noticeable departure from the rising action of the play. At this juncture, we expect Hamlet to clash with his rivals. Instead, we get a deeply philosophical and darkly comic exchange on death, with the gravediggers singing as they toss around bones and Hamlet wondering about the lives of the skeletons before him:

> That skull had a tongue in it and could sing once. . . .
>
> There's another. Why may not that be the skull of a lawyer? Where be his quiddities now, his quillities, his cases, his tenures, and his tricks? Why does he suffer this mad knave now to knock him about the sconce with a dirty shovel and will not tell him of his action of battery?

Later, Hamlet turns from the unfeeling coarseness of the gravediggers to morbid curiosity about the bodies, asking, "How long will a man lie i' th' earth ere he rot?"

The question of what comes after death has been on Hamlet's mind throughout the play. Considering suicide, he wonders "what dreams may come / When we have shuffled off this mortal coil." He seems torn between Catholic and Protestant accounts of the afterlife: Soon after returning from the University of Wittenberg, a center of the Protestant Reformation, Hamlet encounters what appears to be a strikingly Catholic specter—the ghost of his father, claiming his earthly sins must be "burnt and purged away" in purgatory—but he vacillates on whether the ghost can be believed. By the time he meets the gravediggers, Hamlet's questions about the afterlife, still unsolved, turn to the physical realm: He wants to know about the material nature of corpses.

Hamlet's curiosity about bodies is significant not only because it recalls some of the materialistic ideas he entertained earlier in the

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play—that man is nothing more than a "quintessence of dust," or that the dead Polonius is simply a bag of guts—but also because it suggests that Shakespeare was engaging with the science of his time. A half-century before Shakespeare penned *Hamlet*, anatomists made significant advances in their inquiry into the human body that would fundamentally alter how we understand ourselves. In 1543, Andreas Vesalius, known as the father of modern anatomy, published *De humani corporis fabrica* (*On the Fabric of the Human Body*). Around the same time, as Sujata Iyengar points out in her book *Shakespeare's Medical Language* (2011), London's Company of Barber-Surgeons was granted four corpses of executed criminals per year for dissection—and Shakespeare seems to be interested in their work. Anatomical research appears also in other Shakespeare plays. In *Twelfth Night*, for example, Sir Toby speaks of opening up Sir Andrew to look at his liver, and Olivia refers to her beauty being "inventoried" by body part: "*item*, two lips indifferent red; *item*, two gray eyes with lids to them; *item*, one neck, one chin, and so forth." In *Macbeth* we hear an echo of the anatomist's incision in the account of Macbeth's killing of an enemy: "he unseamed him from the nave to th' chops." Why this interest in anatomy?

Shakespeare takes up references to the morbid art, and to other new discoveries, to show that when scientific investigations yield new ideas about nature, what ensues is an altered relation to ourselves. In fact, Shakespeare explores the philosophical, psychological, and cultural impact of many more scientific fields besides human anatomy, reflecting poetically on theories about germs, atoms, matter, falling bodies, planetary motion, heliocentrism, alchemy, the humors, algebra, Arabic numerals, Pythagorean geometry, the number zero, and the infinite. The inquiries that drove Renaissance science, and the universe it disclosed, are deeply integrated into Shakespeare's poetic worlds.

Until relatively recently, Shakespeare's contact with the scientific world has gone largely unnoticed both among scholars and general audiences. Perhaps Shakespeare scholars and audiences don't notice the way he takes up science because they are unfamiliar with much of the science he was exposed to, while most scientists don't see Shakespeare as valuable for reflecting on science because they assume he was unfamiliar with it. Usually, even when readers are made aware of Shakespeare's references to this or that scientific subject—perhaps Hamlet's reference to infinity or Lear's allusions to atomism—these are treated as little more than interesting artifacts, window-dressing to Shakespeare's broader human concerns.

A small but growing number of scholars are now taking up the connection between Shakespeare and science. And, spurred perhaps by science

fiction, by the ways that science factors in the works of key late-modern writers such as Nabokov, Pynchon, and Wallace, and by the rise of scientific themes in contemporary literary fiction, a growing number of readers are aware that writers can and do take up science, and many are interested in what they do with it.

When we familiarize ourselves with the history of science, we see the imaginative worlds Shakespeare creates to demonstrate science's power to shape our self-understanding, and the power of the literary arts to shape our response to science. We also see that Shakespeare was remarkably prescient about the questions that science would raise for our lives. He explores, for example, how we are personally affected by the uncertainties that cosmological science can introduce, or what it means when scientists claim that our first-hand experience is illusory, or how we respond when science probes into matters of the heart.

Hamlet famously tells a group of actors that the purpose of playing is "to hold, as 'twere, the mirror up to nature" and to show "the very age and body of the time his form and pressure." Shakespeare shows us the pressures that science exerted on human life in his time, and his time in this regard remains very much our own. To catch a glimpse at the forms and pressures that we share with Shakespeare, we will turn to some more familiar and some less familiar lines of three well-known plays—*Hamlet*, *King Lear*, and *Romeo and Juliet*—where he interacts with concepts and claims in early modern science. In Shakespeare's poetic meditations on the science of the heavens, of weight, and of disease, we witness how science transforms the ways we think about the world and our relation to ourselves.

The Equivocal Cosmos of *Hamlet*

In *Hamlet*, Shakespeare ponders our status as ensouled yet finite beings by reflecting not only upon earthy bodies but also upon starry skies. When we look at the science of the play, we see that Hamlet's struggles with the Reformation's conflicting accounts of purgatory are compounded by his contact with conflicting scientific accounts of the cosmos. Through subtle but intriguing references to one of the greatest upheavals in modern science—the Copernican Revolution—Shakespeare shows how theoretical shifts in our cosmology bear on human life, especially on matters of love.

One clue that Shakespeare seems to have been engaging with Copernican astronomy comes from the setting of *Hamlet* at Kronborg

Castle, called Elsinore in the play after Helsingør, the Danish city in which it stands. In *The Science of Shakespeare* (2014), a survey of the scholarship on the Bard's contact with science, science journalist Dan Falk points out that the coastal city is just a few miles from the island where Tycho Brahe's famous observatory was built in the late 1570s, and Brahe entertained the Copernican system. His observatory was well known throughout Europe—James VI of Scotland visited there in 1590. The English were also acquainted with Copernican astronomy through the work of astronomer Thomas Digges, particularly a popular 1576 book that included the first partial English translation of Copernicus.

A likewise conjectural hint that Shakespeare may have known of Brahe's work can be found in the frontispiece to Brahe's book *Epistolae astronomicae*, published in 1596, around three years before scholars believe Shakespeare began writing *Hamlet*. The image depicts Brahe surrounded by the crests of sixteen members of his extended family. One is named Rosenkrans, another Guldensteren—variants of Rosencrantz and Guildenstern, the names of two friends of Hamlet. Falk notes that these are among the few character names in the play that are actually Danish. It is not known whether Shakespeare saw this book, and the significance of the frontispiece, along with the origin of the characters' names, remains disputed by scholars—though the coincidence is striking.

But the primary evidence that Shakespeare was engaging with Copernican astronomy is that Hamlet himself seems to be doing so in his letter to Ophelia. The letter appears in Act Two, when her father, Polonius, reads it to Gertrude and Claudius. Polonius has taken the letter from Ophelia after she reports to him on Hamlet's bizarre behavior, and he announces that it contains the explanation for Hamlet's madness. Polonius sees this as a madness of love, but what he holds in his hands speaks to something deeper than that. The letter reads:

> To the celestial, and my soul's idol, the
> most beautified Ophelia.…
>
> Doubt thou the stars are fire,
> Doubt that the sun doth move,
> Doubt truth to be a liar,
> But never doubt I love.

The reference to Copernican astronomy—doubting the motion of the sun—seems clear. But readers today may miss what Shakespeare is suggesting about the equivocations of the Copernican world. These cannot be

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This is one of several versions of the Danish astronomer Tycho Brahe's portrait that appeared as a frontispiece in his books in the 1590s. Among the names of his relatives surrounding the portrait are Rosenkrans and Guldensteren, both on the left side of the image.

recognized until we know, as noted by Howard Marchitello in *The Machine in the Text* (2011) and Leon Harold Craig in *Philosophy and the Puzzles of Hamlet* (2014), that the word "doubt" in Shakespeare's time could mean two opposing things: either to suspect that something is *not* true (the only way we use the word today), or to suspect that something *is* true, to apprehend or fear. We see the latter meaning earlier in the play when Hamlet says, "All is not well. I doubt some foul play." Indeed, "suspect" or "fear" seem the only coherent meaning in "Doubt truth to be a liar."

On one possible reading, Hamlet says that in a world where even the most apparent facts—like the motion of the sun—have been called into doubt, his love remains a certainty. Contrasting the mutability of scientific ideas with the constant knowledge of the heart, this is the most obvious, and romantic, interpretation of these lines.

But for Hamlet, of course, matters of the heart are in fact deeply conflicted. The contrast of the final line might well sound like a case of protesting too much: When even the most apparently unquestionable things have become doubtful, when one suspects *truth itself* "to be a liar," on what basis should one accept the assurance, "But never doubt I love?" Here the alternate meaning of "doubt" in the final line suggests itself: Hamlet is warning Ophelia that his love, like the sun's motion, may be mere appearance. Later, he chides her: "You should not have believed me. . . . I loved you not."

We might be tempted to argue for one reading over another. But the ambiguity of the passage seems to be deliberate, indeed, to be its point. Like his ostensible madness, which seems almost incorrigibly equivocal, Hamlet's love is full of equivocation. Shakespeare connects cosmological doubt with psychic inconstancy—inconstancy of both the heart and the mind.

Hamlet's love for Ophelia seems to oscillate between two views: that she is a celestial, spiritual being to be treated with awe, or that she is simply a material being, lusty and lowly. Hamlet's advice to Ophelia, "Get thee to a nunnery," captures the equivocation of his soul in this regard, for the word "nunnery" in Shakespeare's time referred both to a spiritual home for celibate women and to a brothel. This double, opposed characterization mirrors the opposition between the Ptolemaic and the Copernican worlds, the one emphasizing the spiritual perfection of the heavenly spheres, the other destroying the basis of that ideal, opening up the idea that the celestial world is no different in kind from our lowly material one. Hamlet cannot, as he says at the conclusion of the letter, "reckon my groans." He can't solve for truth in his beloved or in the cosmos.

Hamlet's Copernican conundrum resembles several other, more familiar, equivocal appearances he faces in the play: He cannot discern whether the ghost, who says that he is Hamlet's father and that Claudius killed him in order to marry Hamlet's mother, is his father in purgatory or a demon in hell; he cannot tell whether Claudius is guilty; he cannot determine which account of the afterlife is true.

In the face of these uncertainties, Hamlet is moved to seek a constant basis to guide his actions. Initially, his investigations could be considered quasi-scientific. He attempts to investigate the ghost's truthfulness by staging a play that enacts the murder and carefully observing Claudius's reaction—a kind of empirical test (if a faulty one). He asks the gravedigger how long a man lies in his grave until he rots, and investigates all matters concerning death. Perhaps he thinks that having empirical certainty will help him know what to do. But ultimately, his investigations do not—perhaps cannot—yield the kind of certain answers he seeks.

Hamlet's questions about the afterlife and about the ghost are similar in character to questions about the Copernican universe, at least as they stood at the time: they are unanswerable with natural perception. It is crucial to recall that the Copernican Revolution was not a quick skirmish, as the name might suggest, but rather a protracted struggle—with the first volleys, to simplify matters a bit, fired in 1543 with *On the Revolutions of the Heavenly Spheres* and the last with Newton's *Principia* in 1687. Before Newton, the outcome of the struggle for the cosmos remained an open question. Neither was it certain that there even would be a single victor. Brahe, for example, who had greatly innovated systematic observation with the naked eye, had arrived not at a verdict in favor of Ptolemy's geocentrism or Copernicus's heliocentrism, but a hybrid model—a theory described by historian Christine Schofield as "a safe synthesis of ancient and modern" views. It was not until Galileo augmented the senses with his telescope, publishing his observations and his case for heliocentrism in 1610, that it became clear that empirical investigation might be capable of settling the matter. But *Hamlet*, first published in 1603, pre-dates this shift by just a few years.

For Hamlet, then—as for Shakespeare when the play was written—it may not be possible to adjudicate between the competing accounts of the cosmos on the basis of observation. He evinces a kind of vertigo, not of living in a time when the old cosmic order has been dethroned and a new one installed, but of living in a cosmological interregnum, a power vacuum where the only reigning principle is uncertainty. Hamlet's investigative impulse illustrates how we are sometimes inclined to ask and to

try to answer questions that may be impossible to answer at the time. Shakespeare's implicit comparison between the potentially irresolvable uncertainties of theology and cosmology—the soul's journey after death, the sun's journey around the earth—remind us that we must often live without clear answers. Science may be one source of answers, but it can also present us with claims that science itself cannot immediately verify, and in many cases it cannot offer any answers at all.

Ultimately, Hamlet entertains other bases for action that do not rely on empirical certainty: He tries to imitate the rashness of the revenge hero ("My thoughts be bloody or be nothing worth!"), he entertains the possibility of providence ("There's a divinity that shapes our ends, rough-hew them how we will"), and, in the end, he embraces readiness for death ("There is a special providence in the fall of a sparrow.... The readiness is all"). In the final scene of the play, however, only moments before Hamlet's death, he asks Horatio to halt his own suicide ("Give me the cup. Let go!") so that Horatio can live to tell Hamlet's tale. At the moment of his death, then, Hamlet seems to move from being a contemplative man, who has given himself over to death, to a man who sees in the recollection of his life the possibility of finding some clarity about how to live with uncertainty.

By placing us with Hamlet in a world of theoretical flux, Shakespeare invites us to meditate on the experience of uncertainty—on how doubt that begins as merely scientific can become deeply unsettling, working its way into our hearts and minds, permeating our psyches. Scientific theories remind us regularly of our ignorance; it may even be more characteristic of science to introduce uncertainty than to give us answers. Shakespeare gives us occasion to think through what our most significant actions might look like if they are informed by awareness of our ignorance. We see that Hamlet's offenses—the death of Polonius, the rejection of Ophelia, the deaths of Rosencrantz and Guildenstern—result from misplaced resolution. Shakespeare suggests that, in a world of continually conflicting appearances, the ability to act requires philosophical courage, grounded more in understanding what we do not know than in certainty about what we do.

Atoms and Moral Weight in *King Lear*

In *King Lear*, Shakespeare takes up a theoretical puzzle about the nature of matter and weight that was at the heart of Renaissance physics. Here he explores how shifts in scientific language that undermine commonsense intuitions can destabilize moral metaphors based on those intuitions. As

in *Hamlet*, Shakespeare crafts some of his most profound lines in thinking through how we can continue to act when science seems to be pulling up the anchors of our worldview.

It may be helpful to review the plot of *King Lear* before we proceed. The play is set for tragedy almost from the beginning, when Lear attempts to divide his kingdom into three parts, reserving the most "opulent" part for his youngest daughter, Cordelia. When she refuses to comply with his staged love test—which he purports to use to decide who will get what part of the kingdom, depending on who loves him most—Lear exiles her. In doing so, he unwittingly sets the stage for his own exile, a looming civil war between his other two daughters, the gruesome torture and death of a loyal nobleman, and ultimately the disgraceful end of his reign.

King Lear is striking for how suddenly it devolves into horrific disaster, and we might wonder how any situation could change this quickly. Notably, its move in this direction is not caused simply by evil characters or evil forces. Rather, it has something to do with the way Lear and the other characters think about the world, and particularly about physics.

To see how Renaissance physics works its way into the action of *Lear*, we must take on some challenging interpretive work. References to physics appear in nearly every scene in the play, but they are often subtle, and their meaning is hard to discern. To begin to see how Shakespeare is engaged with physics requires that we take a broad view of the play, attending not only to single lines and exchanges but also to the play's more general language.

In *Losing Touch with Nature: Literature and the New Science in Sixteenth-Century England* (2014), Mary Thomas Crane does a masterful job of gathering the evidence that a broad series of references to weight, matter, and void that appear in *King Lear* are inspired by "atomistic speculations that were disrupting the human relationship with the material world" at the time the play was written. Many scholars argue that these speculations were influenced by revived interest in ancient atomism, particularly that of Lucretius, the ancient Roman philosopher-poet. While Lucretius's didactic poem *On the Nature of Things* was not translated into English until after Shakespeare's death, his work was available in Latin, and was likely familiar to educated Elizabethans, as was the broader tradition of atomistic thought of which he was a key figure. Scholars also suggest a number of sixteenth-century interpretive intermediaries through whom Shakespeare might have known of Lucretius, including Christopher Marlowe, Michel de Montaigne, and the Italian scientist and poet Girolamo Fracastoro. Crane herself argues that contemporary atomism

probably arose not out of engagement with the ancients but out of novel recognition of theoretical problems posed by the prevailing Aristotelian theory, which held that matter can be infinitely divided, and which denied the possibility of empty space.

Whatever the source, Crane points to a number of crucial indications that engagements with atomism are all over the play. (My argument here echoes hers in some places but diverges in others.) First, it is present in Lear's line, "nothing will come of nothing," a metaphysical principle that comes to us from numerous ancient Greek sources—including as a key tenet of *On the Nature of Things*—and was well known in Elizabethan England. Nothing will come from nothing (*ex nihilo nihil fit* in Latin) stands in direct contradiction to the Christian doctrine of creation *ex nihilo*. Atomists who affirm that nothing comes from nothing believe there is no need for any kind of special creation because atoms are eternally present, producing through their various interactions all that exists. Lear seems to treat political power atomistically, acting as though it is ever present and can simply be redistributed as he wishes without any loss in total amount. It is this view of political power that initiates the tragedy of the play, which, as we will see, involves other types of division too. As Crane writes,

> the proliferation of divisions…emerges from an atomistic model of matter.…The play recognizes the social implications of divisions and discord, and, of course, there was a longstanding tradition that dividing a kingdom would cause further rifts.

We also hear echoes of atomism in the play's near-obsession with negation and nothingness: Cordelia's silence in response to Lear's question of who loves him most, characters' lies, the Fool's description of Lear's kingdom as an empty snail's shell, the use of "naught." One of the famous scenes in the play—Lear's fit of madness in the storm—is described in some editions as occurring in "another part of the heath," that is, in a wilderness or uncultivated field. But as Crane, following Henry S. Turner, points out, these stage directions come from a later editorial tradition. In the context of the scene it is better to think of the action as occurring in a giant void, perhaps symbolizing material as well as political vacuum. This void seems to be what is left when, in Lear's words, "nature's molds" are cracked and "all germens spill at once"—namely, nothing. In this sense, *Lear* is an experiment in thinking through whether nothingness or void can have any power. When Lear goes out into the realm of seeming nothingness, we are invited to wonder whether anything that supports life can emerge out of it.

The play also invokes atomism by taking up questions about the kinds of things that can or cannot be quantified and divided. When Lear challenges his daughters to express their love for him as he divides his land into thirds on a map—thirds which are not equal in "bounty"—the daughters seem to take different views on whether love can be quantified. Goneril and Regan treat love as unquantifiable and indivisible. "Sir, I love you more than word can wield the matter," says Goneril, "beyond what can be valued." Regan tries to upstage her older sister, who she says still "comes too short." Cordelia, surprisingly, treats love as though it is divisible and finite. Defending her refusal to wax eloquent, she explains that there is only so much love she can give her father and that when she marries, her husband will need to get "half my love," unlike her sisters, who, giving all their love to their father, would seem to have none left for their husbands. Perhaps at the outset she embraces her father's atomistic views, too.

We also see the play's interest in nature's smallest material parts in its preoccupation with smell and breath. In the atomistic way of thinking, our sense of smell is able to pick up on particles that are less dense than those our eyes observe, although there can be secondary visual signs of them. At the end of the play, we witness a desperate experiment with the signs of particles of breath when Lear is testing whether Cordelia is dead. First he says, "I know when one is dead and when one lives. She's dead as earth." But then immediately he looks for signs of life, asking for a mirror to see if there is condensation when he holds it up against her mouth, and then a feather to see if it might move. To the end, Lear pursues an atomistic, materially observable account of life.

Alongside its references to atomism, the play takes up questions about the nature of weight that were also a focus of changing contemporary ideas about physics. One of the most memorable such moments is in the scene near Dover where the blinded Gloucester believes that Edgar is taking him to the cliffs so he can jump to his death. Shakespeare seems to allude here to the famous experiments with falling objects recently carried out by Galileo and English scientist Thomas Harriot. The falling objects Edgar contrasts in the scene—gossamer, feathers, air, an egg, and the "heavy substance" of Gloucester's body—and the measurement and manner Edgar employs to describe Gloucester's fall—more than the height of ten masts, falling "perpendicularly"—invoke the experiments that established that bodies of different weight fall at the same rate in a vacuum, contrary to what our commonsense intuitions tell us. Gloucester, of course, does not fall off the cliff, but Edgar's conceit is that despite what Gloucester's senses tell him, he has fallen, and his "life's a miracle."

What is particularly striking about this scene (like the scene of Cordelia's death) is that Shakespeare is incorporating the language and questions of physics into the most painful and tragic moments of the play. Why do this? One possible answer is that Shakespeare wants to shed light on the difference between scientific language and the language of moral feeling. Gloucester, though he has some doubts, ultimately ignores his sensory and spatial perceptions and believes Edgar's account of his fall and miraculous survival.

The scene verges on the comical or absurd. But Gloucester's willingness to believe, despite all experience to the contrary, seems to result from his willingness to accept a counterintuitive view of his own weight while entirely suspending his felt experience. Edgar takes advantage of Gloucester's blindness—eyesight being perhaps the most objective of our senses—to convince him that his remaining, more subjective senses deceive him. Why does Shakespeare craft this strange trick?

Shakespeare juxtaposes not two but three different ways of thinking about weight: weight from the perspective of common experience, weight from the perspective of early modern physics, and weight as a metaphor to capture our sense of moral gravity. Common experience gives us the impression that heavy bodies inherently fall faster than lighter bodies. Physics tells us that this impression is false and that bodies actually fall at the same rate (absent the interference of air, anyway). While the relative rate at which bodies fall is not the only basis for our sense of weight, it is a core component of it, and physics at this time seemed to be showing that our intuitive understanding of weight—the one that furnishes our metaphors for moral weightiness—was false.

Shakespeare deploys the moral language of weight throughout his corpus, and particularly frequently in *King Lear*: "just and heavy causes," "the weight of this sad time," "when majesty falls to folly." In the scene of Gloucester's attempted suicide, where he denies his experience and embraces the counterintuitive experimental account of weight, and where moral weightiness is at its heaviest, Shakespeare seems to be inviting us to think through what it means when our moral metaphors start to lose their experiential foundation. Moral seriousness seems to require that we take our personal experience seriously too, whatever scientific evidence there may be to suggest that our experience is, in some significant way, an illusion.

Before Gloucester arrives at Dover, he has been living in a world of moral deceptions. He is vulnerable to these deceptions, as when one of his sons, the illegitimate and jealous Edmund, tricks him into believing that

another son, Edgar, intends patricide. Considering that Edgar seems to have been consistently good-natured, Gloucester is surprisingly quick to accept the lie. His willingness to accept people at face value could align in one of several ways with the tension between commonsense ideas and the new counterintuitive ideas in physics. Most obviously, it suggests the view of the new physics—that the way objects seem to be is a pleasing but false appearance.

But on another reading, Gloucester's susceptibility to deception suggests how accepting the new physics at face value may itself be a kind of gullibility. His tendency toward a naïve surface reading of things seems to go with the crude empiricism of atomism. Atoms in Shakespeare's world are surface kinds of things, indivisible and impenetrable: We cannot have the kind of internal, psychological perspective of them that we have of other human beings. When Gloucester finally realizes that he has been deceived—in contradiction to the surface appearance of things he has embraced—he is left so disoriented as to become nihilistic: He sees the end of his life as the only coherent course of action.

In this light, it is perhaps not a far step for him to entertain Edgar's account of weight and falling bodies, accepting the obvious falsehood that he has fallen. The miraculous quality Edgar ascribes to his father's fictional fall appears to be an attempt to rescue him from a nihilistic stance. In accepting it, Gloucester allows Edgar to recalibrate his father's sense of the gravity of life. However, Edgar does this without appealing to the old experiential metaphors for weight. He gives Gloucester a new view of moral weight based not on sense but on feeling. Edgar says of himself that he has become able to pity others "by the art of known and feeling sorrows." Whereas Gloucester earlier exclaimed in self-loathing that he "will not see because he does not feel," now he says that he sees "feelingly."

By the end of the play, Shakespeare has Edgar call upon his audience to embrace and spread this feeling-based understanding of moral weight. The final lines capture the shift perfectly. As Edgar (or in some versions Albany) says,

> The weight of this sad time we must obey,
> Speak what we feel, not what we ought to say.

Because sense perception can fool us, we are to turn to our feeling of the gravity of the moment, which deepens and redirects our thoughts toward what is morally significant. The audience and the characters alike feel this weight. It is this depth of feeling, and Edgar's acute awareness of it,

that makes it possible for Gloucester to tell Lear that he now sees "feelingly." And it is this empathetic sense of moral weight that Shakespeare counterposes against both the illusory common view of weight and the counterintuitive weight of falling bodies experiments.

Physics can correct our misimpressions about physical weight, but there is a gulf between our understandings of the physical world and of our moral lives. In the early scenes of *King Lear*, the language of atomistic physics—of quantity, division, and void—seems to eclipse the language of feeling. Gloucester and Lear seem unable to perceive their moral worlds rightly because they fail to summon the felt experiences that form the fabric of our moral universe. We ought not to embrace entirely the language of science to think about ourselves, Shakespeare suggests, or we may arrive at a dark, existential absurdity. When science subverts the language that underpins our moral metaphors, our poets must mend the moral fabric for our lives, seeking out a new language to capture our most significant experiences. For Shakespeare, this language is rooted in the pain of pathos rather than in any technical account of matter.

Love Sickness in *Romeo and Juliet*

As in *Hamlet* and *King Lear*, in *Romeo and Juliet* Shakespeare turns to a theoretical world that lies beyond our sense perceptions: the world of germs. Just as he was a poet of Copernican astronomy right before the telescope, so too was he a poet of microbiology just before the first modern microscopes were being developed. But where the theoretical world merely plays on the thoughts of Hamlet and the characters in *Lear*, the world of germs takes hold on Shakespeare's Verona much more directly, altering the course of romantic love.

When we think of *Romeo and Juliet*, we tend to think of it only as a romantic tragedy. We recall the barely missed connection of two young lovers, the kisses and red lips and tombs. We hear the lines "O Romeo, Romeo, wherefore art thou Romeo?" and "But soft, what light through yonder window breaks?" and "What's in a name?" Perhaps we recall a young Leonardo DiCaprio with flushed cheeks, or Claire Danes sporting white swan wings.

Yet when we return to reading the play, we can hardly avoid noticing that gumming up the works of one of the greatest English romances are a series of references to plague, disease, germs, and infection. Mercutio, to note just one example for now, repeats three times his curse "a plague o' both your houses," which he makes halfway through the play, after Tybalt

has landed Mercutio's death blow. It is easy for readers today to interpret the line as metaphorical. But of course, plague was much more than a metaphor in the time when the play was set—probably in the fourteenth century, the time of the Black Death. Even in Shakespeare's day, bubonic plague was still working its course through Verona and its surrounding territories, and epidemics remained frequent in England too.

We might even read Mercutio's curse as causally effective, or at least as prophetic. For the plague indeed enters the story near its end: After Juliet's feigned death, it is the plague that detains Friar John, keeping him from delivering his message to Romeo about the plan to reunite him with Juliet.

A reminder of the plot: After Friar Lawrence has in secret married the two young lovers—Romeo, of the house of Montague, and Juliet, a Capulet—Romeo slays Tybalt (a Capulet) and is ordered into exile. Friar Lawrence urges a despairing Romeo to accept exile, promising that he will help Romeo return to proclaim his marriage to Juliet "with twenty hundred thousand times more joy." Meanwhile, Juliet is forcefully betrothed to Paris, their wedding set to take place in just three days. The Friar concocts a scheme to feign her death for long enough to prevent this second wedding while Romeo returns. Friar Lawrence sends Friar John with a letter to summon Romeo. But Friar John is quarantined because he was suspected to have entered a house "where the infectious pestilence did reign." The message never reaches Romeo, who returns of his own accord. Discovering a Juliet he believes to be dead, he kills himself. She awakes, and, despairing, kills herself as well.

In short, then, the plague prevents that happy return of Romeo that Friar Lawrence envisioned. In this light, the plague exerts the most powerful influence that an event *can* have upon a drama: It causes the plot to swing from comedy to tragedy. So why does Shakespeare have a plague—which causes an "accident," as Friar Lawrence calls Friar John's detention—alter the course of a love story?

Disease in *Romeo and Juliet* is not solely a plot device. Shakespeare wants us to think of love and infection conjointly. We get the first hint of this when Benvolio recommends to Romeo that he simply switch from one "infection to thy eye" to another—meaning that he should turn away from his unrequited love for Rosaline and turn toward someone else. The infection theme persists in Mercutio's speech about the fairies' midwife, Queen Mab, where he expounds playfully to Romeo on how she travels in an empty hazelnut for a chariot, with wheel spokes made of long spider legs, "drawn with a team of little atomi." According to Mercutio, Queen Mab with her little atomi influences everyone's dreams at night. She also

infects ladies' lips with "blisters plagues." In the midst of this long speech, Romeo interrupts Mercutio, begging, "Peace, peace, Mercutio, peace," and Mercutio revises some of what he has said about the origin of dreams. But he does not clearly withdraw his words about the little atomi; their influence, it seems, remains. The blistered lips, too, are hard to forget—especially when Romeo puckers up to kiss Juliet in the next scene.

The mention of atoms clues us in to another theme in the play related to disease: atomism itself, the idea that changes in nature are the effects of the movements of its smallest particles. Atomism is significant to our story about germs because it provides the theoretical foundation for early modern theories about the source of plagues, infections, contagion, and venereal diseases. Again, Shakespeare is writing pre-microscopically, but the thinkers he interacts with are trying to understand the invisible material causes of epidemics, especially of syphilis (introduced to Northern Italy through French soldiers in the late 1400s) and bubonic plague.

One theorist of disease in particular stands out: Girolamo Fracastoro. Fracastoro, as noted above, was a scientist and physician from Verona who embraced atomism; he also made important contributions to theories about the spread of infectious diseases, including syphilis and typhus. His notion of infection resembles Mercutio's account of how Queen Mab exerts her influence: Fracastoro proposed that different kinds of contagious diseases spread by different kinds of tiny particles, or "seeds of contagion," either through direct contact with a sick person, or contact with infected clothes or surfaces, or through the air.

Fracastoro also delivered some of his ideas in the form of epic poems, most notably a famous 1530 poem about syphilis from which the disease got its name. It is plausible that Shakespeare takes the name Mercutio from mercury, sometimes used as a cure for syphilis, and the name Tybalt from typhus, which Fracastoro was the first to describe in detail in his landmark book on contagion. Tybalt's rashness and the speed of action in the play are reminiscent of how infection moves.

Like Fracastoro, Shakespeare uses poetry to convey scientific theory, but he takes this a step further and captures also how science can influence popular thinking—in this case, how atomistic notions of infection contribute to disenchanted attitudes about the nature of romantic love. Nearly all of the secondary characters in the play adopt coarse, reductionistic, and bawdy notions of love. I have mentioned Benvolio's recommendation that Romeo switch infections of the eye. Mercutio gives us a slew of lewd lines, such as his wish that Romeo's lover be "an open-arse." And Nurse

may have the crudest remarks of any character. One, which she mentions three times, echoes her husband's vulgar joke when, after Nurse had put a bitter herb on her nipple to wean a young Juliet, the child fell on her face from shaking: "Fall'st upon thy face? Thou wilt fall backward when thou comest to age, wilt thou not, Jule?"

Nurse's description of Juliet's weaning is another possible echo of the atomism of Lucretius. The bitter herb Nurse used for weaning was wormwood, a key ingredient in absinthe and other spirits, also used to treat various medical conditions, including fatigue, indigestion, and parasitic worms. In *On the Nature of Things*—which is not only a poetic treatise on atomism but also includes an elaborate meditation on love—Lucretius tells us that his disenchanting message is a kind of "wormwood": bitter to the taste but intended for good. (Alternate English translations use "black absynth" or "nauseous draught.") As with *King Lear*, it is arguable whether the allusion is to Lucretius.

The thematic similarity is instructive in any case. Nurse's easygoing coarseness, and her willingness to facilitate the secret marriage of the two young lovers, reminds us of Lucretius's account of love: We should not get so riled up about it. But whereas Lucretius presented his wormwood in the form of sweet lyric poetry to make it go down more easily, Nurse leaves her wormwood pure and plain—her lines are some of the most un-lyrical that Shakespeare ever wrote. In Verona, brute, unromantic material realities—and perhaps also the presence of ideas about how disease and love might be materially caused—have eclipsed more spiritual and romantic visions of love.

Of course, our heroes are quite romantic and have not fallen totally under the influence of their compatriots. But even Romeo and Juliet seem to be confused about how they ought to express and fulfill their desires. When the two first meet, Romeo offers his hand to Juliet as an alternative to his lips, which are "two blushing pilgrims" that stand ready "to smooth that rough touch with a tender kiss." Juliet replies that "saints have hands that pilgrims' hands do touch, / And palm to palm is holy palmers' kiss." A prayer, a kiss, what's the difference? A short dialogue ensues on saintly and physical love before Romeo makes his move. The impasse that the two arrive at is this: He says their kiss purges sin, she says that she takes his sin through his kiss. We cannot help but recall the blistered lips of Mercutio's speech. Is infection the price paid for sinful physicality? The heroes are debating different models of Christian and courtly love, and, at least in the fast courtship of Romeo and Juliet, the debate hinges on how far physical love is sinful.

Against the backdrop of plague-ridden Italy, one can easily imagine how plague or syphilis might be interpreted as a consequence of sin. One can also imagine that this association would push pious would-be lovers into an extreme sort of chastity. Visions of love in Verona seem to be stretching in two directions: On the one hand is the idea of bawdy, lusty physical love that is often mixed with, and likened to, disease; on the other is the idea that all physical love is embroiled with sin—and is to be rejected in favor of more disembodied, saintly expressions.

The debate between these models of love appears repeatedly throughout the play, and remains unresolved at its close. But at least one character has a vision of how Verona can go some length toward resolving it: Friar Lawrence. He offers a response to the debate between Romeo and Juliet by agreeing to marry them, and by preventing them from consummating their marriage until they are wed. He also believes that their marriage may help to turn Capulet and Montague rancor "to pure love." To Friar Lawrence, the potential sinfulness of physical love can be transmuted to something pure if it occurs within marriage, and in a community whose members embrace it thus.

After Romeo slays Tybalt, the Friar takes extraordinary measures to try to continue the possibility of turning rancor into love. He tells Romeo that if he willingly goes into exile, the Friar will find a time when Romeo can proclaim his marriage, reconcile with his friends, beg pardon of the prince, and return to Verona, again, "with twenty hundred thousand times more joy." How will the Friar accomplish this? His tactics involve a bizarre combination of scientific knowledge and religious reformation.

When we first meet Friar Lawrence, he is researching medicinal herbs in order to balance vice and virtue with the help of nature. He looks at herbs with powers both of poison and cure, and, at some point, he acquires medicines that make it possible to feign death and subsequent reawakening—it is this remedy that he will use on Juliet. One suspects that it is her apparent glorious resurrection that will set the stage for three intertwined reconciliations. The Friar, that is, will combine his scientific skill and religious devotion—what Romeo unwittingly calls "holy physic"—to perform an apparent miracle, one that will allow for the reunion of the lovers, the unification of the two fighting houses, and the rehabilitation of conjugal love as a restorative force in the city. What could go wrong?

Of course, the plan fails, for the plague is still rampant. But even what the Friar attempts is fascinating. His planned miracle has the potential to overcome the Veronese people's cynicism about physical love by

bringing conjugal love into the foreground as something to wonder at and celebrate, and by enshrining it as a force of healing of the political community. More broadly, Shakespeare gives us occasion to reflect on how miracles in stories—even when we witness their naturalistic explanations on the same stage—can help to heal us from cynicism by bringing to our attention those aspects of life that are most meaningful and fulfilling.

Shakespeare himself is doing something like what the Friar is doing: He presents us with poetic miracles, and miraculous spectacles, while showing us their non-miraculous causes. It is not just that we know that we are watching a play; it is also that when Shakespeare includes miracles within his plays, he often gives us the explanations behind them. Indeed, along with staged miracles like Gloucester's "fall" in *King Lear*, feigned deaths, reappearances, and resurrections are favorite subjects of Shakespeare's—as Sean Benson has shown in *Shakespearean Resurrection* (2009), they are depicted in a striking number of the plays. There is something about the miracles themselves—even when we know how they work—that Shakespeare wants us to attend to. What does he want us to see?

Shakespeare seems to think that playing poetically with resurrected characters and ambiguous miracles is good for us. At times, perhaps like the morbid one of *Romeo and Juliet*, miraculous stories capture what is meaningful to us. *Romeo and Juliet* displays how the physical and cultural effects of both disease and its scientific explanations can pull us toward the cynical. It also captures the potential generative ability of the human heart to reconstitute meaning even while the mind is engaged with naturalistic reasoning. That we tend to remember the romantic heroes of the play more than the disease that thwarts their love is a testament to the power of poetic meaning. That we can return to their story repeatedly, even when we hear the lines that liken love to a plague, reminds us that Shakespeare's poetic miracles give us more powerful accounts of love than reductive physical ones do—that in giving ourselves over to these miracles we give ourselves over to a source of meaning for our lives.

Scientific Poetics

By the example of his own plays, Shakespeare suggests that one of the poet's most important tasks in an age dominated by science is to survey the full extent of science's power to shape our minds and souls, and then to turn to the poetic imagination in response. He introduces us to new scientific ways of thinking and encourages us to reflect upon the uncertainties and paradoxes that science presents to us. And he shows us how

to create the language and poetic ideas that might help us to counteract science's reductionist tendencies.

Yet Shakespeare does so without dismissing the validity of science; instead, he seeks to understand it. Far from creating a bifurcation by which science and poetry are in separate domains, he embraces the world of science and creates poetic worlds that reflect deeply and philosophically on scientific insights and their human implications, recognizing that science will become deeply enmeshed in our lives. For Shakespeare, poetry has the power to help us to live with the revelations of science, and so science must make way for poetry.