

All of it—the rings of Saturn and my father’s wedding band, the underbelly of the clouds pinked by the rising sun, Einstein’s brain bathing in a jar of formaldehyde, every grain of sand that made the glass that made the jar and each idea Einstein ever had, the shepherdess singing in the Rila mountains of my native Bulgaria and each one of her sheep, every hair on Chance’s velveteen dog ears and Marianne Moore’s red braid and the whiskers of Montaigne’s cat, every translucent fingernail on my friend Amanda’s newborn son, every stone with which Virginia Woolf filled her coat pockets before wading into the River Ouse to drown, every copper atom composing the disc that carried arias aboard the first human-made object to enter interstellar space and every oak splinter of the floorboards onto which Beethoven collapsed in the fit of fury that cost him his hearing, the wetness of every tear that has ever been wept over a grave and the sheen on the beak of every raven that has ever watched the weepers, every cell in Galileo’s fleshy finger and every molecule of gas and dust that made the moons of Jupiter to which it pointed, the Dipper of freckles constellating the olive firmament of a certain forearm I love and every axonal flutter of the tenderness with which I love her, all the facts and figments by which we are perpetually figuring and reconfiguring reality—it all banged into being 13.8 billion years ago from a single source, no louder than the

opening note of Beethoven's Fifth Symphony, no larger than the dot levitating over the small *i*, the *I* lowered from the pedestal of ego.

How can we know this and still succumb to the illusion of separateness, of otherness? This veneer must have been what the confluence of accidents and atoms known as Dr. Martin Luther King, Jr., saw through when he spoke of our "inescapable network of mutuality," what Walt Whitman punctured when he wrote that "every atom belonging to me as good belongs to you."

One autumn morning, as I read a dead poet's letters in my friend Wendy's backyard in San Francisco, I glimpse a fragment of that atomic mutuality. Midsentence, my peripheral vision—that glory of instinct honed by millennia of evolution—pulls me toward a miraculous sight: a small, shimmering red leaf twirling in midair. It seems for a moment to be dancing its final descent. But no—it remains suspended there, six feet above ground, orbiting an invisible center by an invisible force. For an instant I can see how such imperceptible causalities could drive the human mind to superstition, could impel medieval villagers to seek explanation in magic and witchcraft. But then I step closer and notice a fine spider's web glistening in the air above the leaf, conspiring with gravity in this spinning miracle.

Neither the spider has planned for the leaf nor the leaf for the spider—and yet there they are, an accidental pendulum propelled by the same forces that cradle the moons of Jupiter in orbit, animated into this ephemeral early-morning splendor by eternal cosmic laws impervious to beauty and indifferent to meaning, yet replete with both to the bewildered human consciousness beholding it.

We spend our lives trying to discern where we end and the rest of the world begins. We snatch our freeze-frame of life from the simultaneity of existence by holding on to illusions of permanence, congruence, and linearity; of static selves and lives that unfold in sensical narratives. All the while, we mistake chance for choice, our labels and models of things for the things themselves, our records for our history. History is not what happened, but what survives the shipwrecks of judgment and chance.

Some truths, like beauty, are best illuminated by the sidewise gleam of figuring, of meaning-making. In the course of our figur-

ing, orbits intersect, often unbeknownst to the bodies they carry—intersections mappable only from the distance of decades or centuries. Facts crosshatch with other facts to shade in the nuances of a larger truth—not relativism, no, but the mightiest realism we have. We slice through the simultaneity by being everything at once: our first names and our last names, our loneliness and our society, our bold ambition and our blind hope, our unrequited and part-requited loves. Lives are lived in parallel and perpendicular, fathomed nonlinearly, figured not in the straight graphs of “biography” but in many-sided, many-splendored diagrams. Lives interweave with other lives, and out of the tapestry arise hints at answers to questions that raze to the bone of life: What are the building blocks of character, of contentment, of lasting achievement? How does a person come into self-possession and sovereignty of mind against the tide of convention and unreasoning collectivism? Does genius suffice for happiness, does distinction, does love? Two Nobel Prizes don’t seem to recompense the melancholy radiating from every photograph of the woman in the black laboratory dress. Is success a guarantee of fulfillment, or merely a promise as precarious as a marital vow? How, in this blink of existence bookended by nothingness, do we attain completeness of being?

There are infinitely many kinds of beautiful lives.

So much of the beauty, so much of what propels our pursuit of truth, stems from the invisible connections—between ideas, between disciplines, between the denizens of a particular time and a particular place, between the interior world of each pioneer and the mark they leave on the cave walls of culture, between faint figures who pass each other in the nocturne before the torchlight of a revolution lights the new day, with little more than a half-nod of kinship and a match to change hands.

## ONLY THE DREAMER WAKES

This is how I picture it:

A spindly middle-aged mathematician with a soaring mind, a sunken heart, and bad skin is being thrown about the back of a carriage in the bone-hollowing cold of a German January. Since his youth, he has been inscribing into family books and friendship albums his personal motto, borrowed from a verse by the ancient poet Perseus: “O the cares of man, how much of everything is futile.” He has weathered personal tragedies that would level most. He is now racing through the icy alabaster expanse of the countryside in the precarious hope of averting another: Four days after Christmas and two days after his forty-fourth birthday, a letter from his sister has informed him that their widowed mother is on trial for witchcraft—a fact for which he holds himself responsible.

He has written the world’s first work of science fiction—a clever allegory advancing the controversial Copernican model of the universe, describing the effects of gravity decades before Newton formalized it into a law, envisioning speech synthesis centuries before computers, and presaging space travel three hundred years before the Moon landing. The story, intended to counter superstition with science through symbol and metaphor inviting critical thinking, has instead effected the deadly indictment of his elderly, illiterate mother.

The year is 1617. His name is Johannes Kepler—perhaps the

unluckiest man in the world, perhaps the greatest scientist who ever lived. He inhabits a world in which God is mightier than nature, the Devil realer and more omnipresent than gravity. All around him, people believe that the sun revolves around the Earth every twenty-four hours, set into perfect circular motion by an omnipotent creator; the few who dare support the tendentious idea that the Earth rotates around its axis while revolving around the sun believe that it moves along a perfectly circular orbit. Kepler would disprove both beliefs, coin the word *orbit*, and quarry the marble out of which classical physics would be sculpted. He would be the first astronomer to develop a scientific method of predicting eclipses and the first to link mathematical astronomy to material reality—the first astrophysicist—by demonstrating that physical forces move the heavenly bodies in calculable ellipses. All of this he would accomplish while drawing horoscopes, espousing the spontaneous creation of new animal species rising from bogs and oozing from tree bark, and believing the Earth itself to be an ensouled body that has digestion, that suffers illness, that inhales and exhales like a living organism. Three centuries later, the marine biologist and writer Rachel Carson would reimagine a version of this view woven of science and stripped of mysticism as she makes *ecology* a household word.

Kepler's life is a testament to how science does for reality what Plutarch's thought experiment known as "the Ship of Theseus" does for the self. In the ancient Greek allegory, Theseus—the founder-king of Athens—sailed triumphantly back to the great city after slaying the mythic Minotaur on Crete. For a thousand years, his ship was maintained in the harbor of Athens as a living trophy and was sailed to Crete annually to reenact the victorious voyage. As time began to corrode the vessel, its components were replaced one by one—new planks, new oars, new sails—until no original part remained. Was it then, Plutarch asks, the same ship? There is no static, solid self. Throughout life, our habits, beliefs, and ideas evolve beyond recognition. Our physical and social environments change. Almost all of our cells are replaced. Yet we remain, to ourselves, "who" "we" "are."

So with science: Bit by bit, discoveries reconfigure our understanding of reality. This reality is revealed to us only in fragments. The more fragments we perceive and parse, the more lifelike the mosaic we make of them. But it is still a mosaic, a representation—imperfect and incomplete, however beautiful it may be, and subject to unending transfiguration. Three centuries after Kepler, Lord Kelvin would take the podium at the British Association of Science in the year 1900 and declare: “There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.” At the same moment in Zurich, the young Albert Einstein is incubating the ideas that would converge into his revolutionary conception of spacetime, irreversibly transfiguring our elemental understanding of reality.

Even the farthest seers can’t bend their gaze beyond their era’s horizon of possibility, but the horizon shifts with each incremental revolution as the human mind peers outward to take in nature, then turns inward to question its own givens. We sieve the world through the mesh of these certitudes, tautened by nature and culture, but every once in a while—whether by accident or conscious effort—the wire loosens and the kernel of a revolution slips through.

Kepler first came under the thrall of the heliocentric model as a student at the Lutheran University of Tübingen half a century after Copernicus published his theory. The twenty-two-year-old Kepler, studying to enter the clergy, wrote a dissertation about the Moon, aimed at demonstrating the Copernican claim that the Earth is moving simultaneously around its axis and around the sun. A classmate by the name of Christoph Besold—a law student at the university—was so taken with Kepler’s lunar paper that he proposed a public debate. The university promptly vetoed it. A couple of years later, Galileo would write to Kepler that he’d been a believer in the Copernican system himself “for many years”—and yet he hadn’t yet dared to stand up for it in public and wouldn’t for more than thirty years.

Kepler's radical ideas rendered him too untrustworthy for the pulpit. After graduation, he was banished across the country to teach mathematics at a Lutheran seminary in Graz. But he was glad—he saw himself, mind and body, as cut out for scholarship. “I take from my mother my bodily constitution,” he would later write, “which is more suited to study than to other kinds of life.” Three centuries later, Walt Whitman would observe how beholden the mind is to the body, “how behind the tally of genius and morals stands the stomach, and gives a sort of casting vote.”

While Kepler saw his body as an instrument of scholarship, other bodies around him were being exploited as instruments of superstition. In Graz, he witnessed dramatic exorcisms performed on young women believed to be possessed by demons—grim public spectacles staged by the king and his clergy. He saw brightly colored fumes emanate from one woman's belly and glistening black beetles crawl out of another's mouth. He saw the deftness with which the puppeteers of the populace dramatized dogma to wrest control—the church was then the mass media, and the mass media were as unafraid of resorting to propaganda as they are today.

As religious persecution escalated—soon it would erupt into the Thirty Years' War, the deadliest religious war in the Continent's history—life in Graz became unlivable. Protestants were forced to marry by Catholic ritual and have their children baptized as Catholics. Homes were raided, heretical books confiscated and destroyed. When Kepler's infant daughter died, he was fined for evading the Catholic clergy and not allowed to bury his child until he paid the charge. It was time to migrate—a costly and trying endeavor for the family, but Kepler knew there would be a higher price to pay for staying:

I may not regard loss of property more seriously than loss of opportunity to fulfill that for which nature and career have destined me.

Returning to Tübingen for a career in the clergy was out of the question:

I could never torture myself with greater unrest and anxiety than if I now, in my present state of conscience, should be enclosed in that sphere of activity.

Instead, Kepler reconsidered something he had initially viewed merely as a flattering compliment to his growing scientific reputation: an invitation to visit the prominent Danish astronomer Tycho Brahe in Bohemia, where he had just been appointed royal mathematician to the Holy Roman Emperor.

Kepler made the arduous five-hundred-kilometer journey to Prague. On February 4, 1600, the famous Dane welcomed him warmly into the castle where he computed the heavens, his enormous orange mustache almost aglow with geniality. During the two months Kepler spent there as guest and apprentice, Tycho was so impressed with the young astronomer's theoretical ingenuity that he permitted him to analyze the celestial observations he had been guarding closely from all other scholars, then offered him a permanent position. Kepler accepted gratefully and journeyed back to Graz to collect his family, arriving in a retrograde world even more riven by religious persecution. When the Keplers refused to convert to Catholicism, they were banished from the city—the migration to Prague, with all the privations it would require, was no longer optional. Shortly after Kepler and his family alighted in their new life in Bohemia, the valve between chance and choice opened again, and another sudden change of circumstance flooded in: Tycho died unexpectedly at the age of fifty-four. Two days later, Kepler was appointed his successor as imperial mathematician, inheriting Tycho's data. Over the coming years, he would draw on it extensively in devising his three laws of planetary motion, which would revolutionize the human understanding of the universe.

How many revolutions does the cog of culture make before a new truth about reality catches into gear?

Three centuries before Kepler, Dante had marveled in his *Divine Comedy* at the new clocks ticking in England and Italy: "One wheel moves and drives the other." This marriage of technology and poetry eventually gave rise to the metaphor of the clockwork uni-



verse. Before Newton's physics placed this metaphor at the ideological epicenter of the Enlightenment, Kepler bridged the poetic and the scientific. In his first book, *The Cosmographic Mystery*, Kepler picked up the metaphor and stripped it of its divine dimensions, removing God as the clockmaster and instead pointing to a single force operating the heavens: "The celestial machine," he wrote, "is not something like a divine organism, but rather something like a clockwork in which a single weight drives all the gears." Within it, "the totality of the complex motions is guided by a single magnetic force." It was not, as Dante wrote, "love that moves the sun and other stars"—it was gravity, as Newton would later formalize this "single magnetic force." But it was Kepler who thus formulated for the first time the very notion of a force—something that didn't exist for Copernicus, who, despite his groundbreaking insight that the sun moves the planets, still conceived of that motion in poetic rather than scientific terms. For him, the planets were horses whose reins the sun held; for Kepler, they were gears the sun wound by a physical force.

In the anxious winter of 1617, unfigurative wheels are turning beneath Johannes Kepler as he hastens to his mother's witchcraft trial. For this long journey by horse and carriage, Kepler has packed a battered copy of *Dialogue on Ancient and Modern Music* by Vincenzo Galilei, his sometime friend Galileo's father—one of the era's most influential treatises on music, a subject that always enchanted Kepler as much as mathematics, perhaps because he never saw the two as separate. Three years later, he would draw on it in composing his own groundbreaking book *The Harmony of the World*, in which he would formulate his third and final law of planetary motion, known as the harmonic law—his exquisite discovery, twenty-two years in the making, of the proportional link between a planet's orbital period and the length of the axis of its orbit. It would help compute, for the first time, the distance of the planets from the sun—the measure of the heavens in an era when the Solar System was thought to be all there was.

As Kepler is galloping through the German countryside to prevent his mother's execution, the Inquisition in Rome is about to

declare the claim of Earth's motion heretical—a heresy punishable by death.

Behind him lies a crumbled life: Emperor Rudolph II is dead—Kepler is no longer royal mathematician and chief scientific adviser to the Holy Roman Emperor, a job endowed with Europe's highest scientific prestige, though primarily tasked with casting horoscopes for royalty; his beloved six-year-old son is dead—"a hyacinth of the morning in the first day of spring" wilted by smallpox, a disease that had barely spared Kepler himself as a child, leaving his skin cratered by scars and his eyesight permanently damaged; his first wife is dead, having come unhinged by grief before succumbing to the pox herself.

Before him lies the collision of two worlds in two world systems, the spark of which would ignite the interstellar imagination.

In 1609, Johannes Kepler finished the first work of genuine science fiction—that is, imaginative storytelling in which sensical science is a major plot device. *Somnium*, or *The Dream*, is the fictional account of a young astronomer who voyages to the Moon. Rich in both scientific ingenuity and symbolic play, it is at once a masterpiece of the literary imagination and an invaluable scientific document, all the more impressive for the fact that it was written before Galileo pointed the first spyglass at the sky and before Kepler himself had ever looked through a telescope.

Kepler knew what we habitually forget—that the locus of possibility expands when the unimaginable is imagined and then made real through systematic effort. Centuries later, in a 1971 conversation with Carl Sagan and Arthur C. Clarke about the future of space exploration, science fiction patron saint Ray Bradbury would capture this transmutation process perfectly: "It's part of the nature of man to start with romance and build to a reality." Like any currency of value, the human imagination is a coin with two inseparable sides. It is our faculty of fancy that fills the disquieting gaps of the unknown with the tranquilizing certitudes of myth and superstition, that points to magic and witchcraft when common sense and

reason fail to unveil causality. But that selfsame faculty is also what leads us to rise above accepted facts, above the limits of the possible established by custom and convention, and reach for new summits of previously unimagined truth. Which way the coin flips depends on the degree of courage, determined by some incalculable combination of nature, culture, and character.

In a letter to Galileo containing the first written mention of *The Dream*'s existence and penned in the spring of 1610—a little more than a century after Columbus voyaged to the Americas—Kepler ushers his correspondent's imagination toward fathoming the impending reality of interstellar travel by reminding him just how unimaginable transatlantic travel had seemed not so long ago:

Who would have believed that a huge ocean could be crossed more peacefully and safely than the narrow expanse of the Adriatic, the Baltic Sea or the English Channel?

Kepler envisions that once “sails or ships fit to survive the heavenly breezes” are invented, voyagers would no longer fear the dark emptiness of interstellar space. With an eye to these future explorers, he issues a solidary challenge:

So, for those who will come shortly to attempt this journey, let us establish the astronomy: Galileo, you of Jupiter, I of the moon.

Newton would later refine Kepler's three laws of motion with his formidable calculus and richer understanding of the underlying force as the foundation of Newtonian gravity. In a quarter millennium, the mathematician Katherine Johnson would draw on these laws in computing the trajectory that lands *Apollo 11* on the Moon. They would guide the *Voyager* spacecraft, the first human-made object to sail into interstellar space.

In *The Dream*, which Kepler described in his letter to Galileo as a “lunar geography,” the young traveler lands on the Moon to find that lunar beings believe Earth revolves around them—from their cosmic vantage point, our pale blue dot rises and sets against their

firmament, something reflected even in the name they have given Earth: Volva. Kepler chose the name deliberately, to emphasize the fact of Earth's revolution—the very motion that made Copernicanism so dangerous to the dogma of cosmic stability. Assuming that the reader is aware that the Moon revolves around the Earth—an anciently observed fact, thoroughly uncontroversial by his day—Kepler intimates the unnerving central question: Could it be, his story suggests in a stroke of allegorical genius predating Edwin Abbott's *Flatland* by nearly three centuries, that our own certitude about Earth's fixed position in space is just as misguided as the lunar denizens' belief in Volva's revolution around them? Could we, too, be revolving around the sun, even though the ground feels firm and motionless beneath our feet?

*The Dream* was intended to gently awaken people to the truth of Copernicus's disconcerting heliocentric model of the universe, defying the long-held belief that Earth is the static center of an immutable cosmos. But earthlings' millennia-long slumber was too deep for *The Dream*—a deadly somnolence, for it resulted in Kepler's elderly mother's being accused of witchcraft. Tens of thousands of people would be tried for witchcraft by the end of the persecution in Europe, dwarfing the two dozen who would render Salem synonymous with witchcraft trials seven decades later. Most of the accused were women, whose inculpation or defense fell on their sons, brothers, and husbands. Most of the trials ended in execution. In Germany, some twenty-five thousand were killed. In Kepler's sparsely populated hometown alone, six women had been burned as witches just a few weeks before his mother was indicted.

An uncanny symmetry haunts Kepler's predicament—it was Katharina Kepler who had first enchanted her son with astronomy when she took him to the top of a nearby hill and let the six-year-old boy gape in wonderment as the Great Comet of 1577 blazed across the sky.

By the time he wrote *The Dream*, Kepler was one of the most prominent scientists in the world. His rigorous fidelity to observa-

tional data harmonized with a symphonic imagination. Drawing on Tycho's data, Kepler devoted a decade and more than seventy failed trials to calculating the orbit of Mars, which became the yardstick for measuring the heavens. Having just formulated the first of his laws, demolishing the ancient belief that the heavenly bodies obey uniform circular motion, Kepler demonstrated that the planets orbit the sun at varying speeds along ellipses. Unlike previous models, which were simply mathematical hypotheses, Kepler discovered the actual orbit by which Mars moved through space, then used the Mars data to determine Earth's orbit. Taking multiple observations of Mars's position relative to Earth, he examined how the angle between the two planets changed over the course of the orbital period he had already calculated for Mars: 687 days. To do this, Kepler had to project himself onto Mars with an empathic leap of the imagination. The word *empathy* would come into popular use three centuries later, through the gateway of art, when it entered the modern lexicon in the early twentieth century to describe the imaginative act of projecting oneself into a painting in an effort to understand why art moves us. Through science, Kepler had projected himself into the greatest work of art there is in an effort to understand how nature draws its laws to move the planets, including the body that moves us through space. Using trigonometry, he calculated the distance between Earth and Mars, located the center of Earth's orbit, and went on to demonstrate that all the other planets also moved along elliptical orbits, thus demolishing the foundation of Greek astronomy—uniform circular motion—and effecting a major strike against the Ptolemaic model.

Kepler published these revelatory results, which summed up his first two laws, in his book *Astronomia nova*—*The New Astronomy*. That is exactly what it was—the nature of the cosmos had forever changed, and so had our place in it. “Through my effort God is being celebrated in astronomy,” Kepler wrote to his former professor, reflecting on having traded a career in theology for the conquest of a greater truth.

By the time of *Astronomia nova*, Kepler had ample mathematical evidence affirming Copernicus's theory. But he realized something

crucial and abiding about human psychology: The scientific proof was too complex, too cumbersome, too abstract to persuade even his peers, much less the scientifically illiterate public; it wasn't data that would dismantle their celestial parochialism, but storytelling. Three centuries before the poet Muriel Rukeyser wrote that "the universe is made of stories, not of atoms," Kepler knew that whatever the composition of the universe may be, its understanding was indeed the work of stories, not of science—that what he needed was a new rhetoric by which to illustrate, in a simple yet compelling way, that the Earth is indeed in motion. And so *The Dream* was born.

Even in medieval times, the Frankfurt Book Fair was one of the world's most fecund literary marketplaces. Kepler attended it frequently in order to promote his own books and to stay informed about other important scientific publications. He brought the manuscript of *The Dream* with him to this safest possible launchpad, where the other attendees, in addition to being well aware of the author's reputation as a royal mathematician and astronomer, were either scientists themselves or erudite enough to appreciate the story's clever allegorical play on science. But something went awry: Sometime in 1611, the sole manuscript fell into the hands of a wealthy young nobleman and made its way across Europe. By Kepler's account, it even reached John Donne and inspired his ferocious satire of the Catholic Church, *Ignatius His Conclave*. Circulated via barbershop gossip, versions of the story had reached minds far less literary, or even literate, by 1615. These garbled retellings eventually made their way to Kepler's home duchy.

"Once a poem is made available to the public, the right of interpretation belongs to the reader," young Sylvia Plath would write to her mother three centuries later. But interpretation invariably reveals more about the interpreter than about the interpreted. The gap between intention and interpretation is always rife with wrongs, especially when writer and reader occupy vastly different strata of emotional maturity and intellectual sophistication. The science, symbolism, and allegorical virtuosity of *The Dream* were entirely lost on the illiterate, superstitious, and vengeful villagers of Kepler's

hometown. Instead, they interpreted the story with the only tool at their disposal—the blunt weapon of the literal shorn of context. They were especially captivated by one element of the story: The narrator is a young astronomer who describes himself as “by nature eager for knowledge” and who had apprenticed with Tycho Brahe. By then, people far and wide knew of Tycho’s most famous pupil and imperial successor. Perhaps it was a point of pride for locals to have produced the famous Johannes Kepler, perhaps a point of envy. Whatever the case, they immediately took the story to be not fiction but autobiography. This was the seedbed of trouble: Another main character was the narrator’s mother—an herb doctor who conjures up spirits to assist her son in his lunar voyage. Kepler’s own mother was an herb doctor.

Whether what happened next was the product of intentional malevolent manipulation or the unfortunate workings of ignorance is hard to tell. My own sense is that one aided the other, as those who stand to gain from the manipulation of truth often prey on those bereft of critical thinking. According to Kepler’s subsequent account, a local barber overheard the story and seized upon the chance to cast Katharina Kepler as a witch—an opportune accusation, for the barber’s sister Ursula had a bone to pick with the elderly woman, a disavowed friend. Ursula Reinhold had borrowed money from Katharina Kepler and never repaid it. She had also confided in the old widow about having become pregnant by a man other than her husband. In an act of unthinking indiscretion, Katharina had shared this compromising information with Johannes’s younger brother, who had then just as unthinkingly circulated it around the small town. To abate scandal, Ursula had obtained an abortion. To cover up the brutal corporeal aftermath of this medically primitive procedure, she blamed her infirmity on a spell—cast against her, she proclaimed, by Katharina Kepler. Soon Ursula persuaded twenty-four suggestible locals to give accounts of the elderly woman’s sorcery—one neighbor claimed that her daughter’s arm had grown numb after Katharina brushed against it in the street; the butcher’s wife swore that pain pierced her husband’s thigh when Katharina walked by; the limping schoolmaster dated the onset

of his disability to a night ten years earlier when he had taken a sip from a tin cup at Katharina's house while reading her one of Kepler's letters. She was accused of appearing magically through closed doors, of having caused the deaths of infants and animals. *The Dream*, Kepler believed, had furnished the superstition-hungry townspeople with evidence of his mother's alleged witchcraft—after all, her own son had depicted her as a sorcerer in his story, the allegorical nature of which eluded them completely.

For her part, Katharina Kepler didn't help her own case. Prickly in character and known to brawl, she first tried suing Ursula for slander—a strikingly modern American approach but, in medieval Germany, effective only in stoking the fire, for Ursula's well-connected family had ties to local authorities. Then she tried bribing the magistrate into dismissing her case by offering him a silver chalice, which was promptly interpreted as an admission of guilt, and the civil case was escalated to a criminal trial for witchcraft.

In the midst of this tumult, Kepler's infant daughter, named for his mother, died of epilepsy, followed by another son, four years old, of smallpox.

Having taken his mother's defense upon himself as soon as he first learned of the accusation, the bereaved Kepler devoted six years to the trial, all the while trying to continue his scientific work and to see through the publication of the major astronomical catalog he had been composing since he inherited Tycho's data. Working remotely from Linz, Kepler first wrote various petitions on Katharina's behalf, then mounted a meticulous legal defense in writing. He requested trial documentation of witness testimonies and transcripts of his mother's interrogations. He then journeyed across the country once more, sitting with Katharina in prison and talking with her for hours on end to assemble information about the people and events of the small town he had left long ago. Despite the allegation that she was demented, the seventy-something Katharina's memory was astonishing—she recalled in granular detail incidents that had taken place years earlier.

Kepler set out to disprove each of the forty-nine "points of disgrace" hurled against his mother, using the scientific method to



uncover the natural causes behind the supernatural evils she had allegedly wrought on the townspeople. He confirmed that Ursula had had an abortion, that the teenaged girl had numbed her arm by carrying too many bricks, that the schoolmaster had lamed his leg by tripping into a ditch, that the butcher suffered from lumbago.

None of Kepler's epistolary efforts at reason worked. Five years into the ordeal, an order for Katharina's arrest was served. In the small hours of an August night, armed guards barged into her daughter's house and found Katharina, who had heard the disturbance, hiding in a wooden linen chest—naked, as she often slept during the hot spells of summer. By one account, she was permitted to clothe herself before being taken away; by another, she was carried out disrobed inside the trunk to avoid a public disturbance and hauled to prison for another interrogation. So gratuitous was the fabrication of evidence that even Katharina's composure through the indignities was held against her—the fact that she didn't cry during the proceedings was cited as proof of unrepentant liaison with the Devil. Kepler had to explain to the court that he had never seen his stoic mother shed a single tear—not when his father left in Johannes's childhood, not during the long years Katharina spent raising her children alone, not in the many losses of old age.

Katharina was threatened with being stretched on a wheel—a diabolical device commonly used to extract confessions—unless she admitted to sorcery. This elderly woman, who had outlived her era's life expectancy by decades, would spend the next fourteen months imprisoned in a dark room, sitting and sleeping on the stone floor to which she was shackled with a heavy iron chain. She faced the threats with self-possession and confessed nothing.

In a last recourse, Kepler uprooted his entire family, left his teaching position, and traveled again to his hometown as the Thirty Years' War raged on. I wonder if he wondered during that dispiriting journey why he had written *The Dream* in the first place, wondered whether the price of any truth is to be capped at so great a personal cost.

Long ago, as a student at Tübingen, Kepler had read Plutarch's *The Face on the Moon*—the mythical story of a traveler who sails

to a group of islands north of Britain inhabited by people who know secret passages to the Moon. There is no science in Plutarch's story—it is pure fantasy. And yet it employs the same simple, clever device that Kepler himself would use in *The Dream* fifteen centuries later to unsettle the reader's anthropocentric bias: In considering the Moon as a potential habitat for life, Plutarch pointed out that the idea of life in saltwater seems unfathomable to air-breathing creatures such as ourselves, and yet life in the oceans exists. It would be another eighteen centuries before we would fully awaken not only to the fact of marine life but to the complexity and splendor of this barely fathomable reality when Rachel Carson pioneered a new aesthetic of poetic science writing, inviting the human reader to consider Earth from the nonhuman perspective of sea creatures.

Kepler first read Plutarch's story in 1595, but it wasn't until the solar eclipse of 1605, the observations of which first gave him the insight that the orbits of the planets were ellipses rather than circles, that he began seriously considering the allegory as a means of illustrating Copernican ideas. Where Plutarch had explored space travel as metaphysics, Kepler made it a sandbox for real physics, exploring gravity and planetary motion. In writing about the take-off of his imaginary spaceship, for instance, he makes clear that he has a theoretical model of gravity factoring in the demands that breaking away from Earth's gravitational grip would place on cosmic voyagers. He goes on to add that while leaving Earth's gravitational pull would be toilsome, once the spaceship is in the gravity-free "aether," hardly any force would be needed to keep it in motion—an early understanding of inertia in the modern sense, predating by decades Newton's first law of motion, which states that a body will move at a steady velocity unless acted upon by an outside force.

In a passage at once insightful and amusing, Kepler describes the physical requirements for his lunar travelers—a prescient description of astronaut training:

No inactive persons are accepted . . . no fat ones; no pleasure-loving ones; we choose only those who have spent their lives on horseback,

or have shipped often to the Indies and are accustomed to subsisting on hardtack, garlic, dried fish and unpalatable fare.

Three centuries later, the early polar explorer Ernest Shackleton would post a similar recruitment ad for his pioneering Antarctic expedition:

Men wanted for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful, honor and recognition in case of success.

When a woman named Peggy Peregrine expressed interest on behalf of an eager female trio, Shackleton dryly replied: “There are no vacancies for the opposite sex on the expedition.” Half a century later, the Russian cosmonaut Valentina Tereshkova would become the first woman to exit Earth’s atmosphere on a spacecraft guided by Kepler’s laws.

After years of exerting reason against superstition, Kepler ultimately succeeded in getting his mother acquitted. But the seventy-five-year-old woman never recovered from the trauma of the trial and the bitter German winter spent in the unheated prison. On April 13, 1622, shortly after she was released, Katharina Kepler died, adding to her son’s litany of losses. A quarter millennium later, Emily Dickinson would write in a poem the central metaphor of which draws on Kepler’s legacy:

Each that we lose takes part of us;  
A crescent still abides,  
Which like the moon, some turbid night,  
Is summoned by the tides.

A few months after his mother’s death, Kepler received a letter from Christoph Besold—the classmate who had stuck up for his lunar dissertation thirty years earlier, now a successful attorney and professor of law. Having witnessed Katharina’s harrowing fate, Besold had worked to expose the ignorance and abuses of power

that sealed it, procuring a decree from the duke of Kepler's home duchy prohibiting any other witchcraft trials unsanctioned by the Supreme Court in the urban and presumably far less superstitious Stuttgart. "While neither your name nor that of your mother is mentioned in the edict," Besold wrote to his old friend, "everyone knows that it is at the bottom of it. You have rendered an inestimable service to the whole world, and someday your name will be blessed for it."

Kepler was unconsolated by the decree—perhaps he knew that policy change and cultural change are hardly the same thing, existing on different time scales. He spent the remaining years of his life obsessively annotating *The Dream* with two hundred twenty-three footnotes—a volume of hypertext equal to the story itself—intended to dispel superstitious interpretations by delineating his exact scientific reasons for using the symbols and metaphors he did.

In his ninety-sixth footnote, Kepler plainly stated "the hypothesis of the whole dream": "an argument for the motion of the Earth, or rather a refutation of arguments constructed, on the basis of perception, against the motion of the Earth." Fifty footnotes later, he reiterated the point by asserting that he envisioned the allegory as "a pleasant retort" to Ptolemaic parochialism. In a trailblazing systematic effort to unmoor scientific truth from the illusions of commonsense perception, he wrote:

Everyone says it is plain that the stars go around the earth while the Earth remains still. I say that it is plain to the eyes of the lunar people that our Earth, which is their Volva, goes around while their moon is still. If it be said that the lunatic perceptions of my moon-dwellers are deceived, I retort with equal justice that the terrestrial senses of the Earth-dwellers are devoid of reason.

In another footnote, Kepler defined gravity as "a power similar to magnetic power—a mutual attraction," and described its chief law:

The attractive power is greater in the case of two bodies that are near to each other than it is in the case of bodies that are far apart.

Therefore, bodies more strongly resist separation one from the other when they are still close together.

A further footnote pointed out that gravity is a universal force affecting bodies beyond the Earth, and that lunar gravity is responsible for earthly tides: “The clearest evidence of the relationship between earth and the moon is the ebb and flow of the seas.” This fact, which became central to Newton’s laws and which is now so commonplace that schoolchildren point to it as plain evidence of gravity, was far from accepted in Kepler’s scientific community. Galileo, who was right about so much, was also wrong about so much—something worth remembering as we train ourselves in the cultural acrobatics of nuanced appreciation without idolatry. Galileo believed, for instance, that comets were vapors of the earth—a notion Tycho Brahe disproved by demonstrating that comets are celestial objects moving through space along computable trajectories after observing the very comet that had made six-year-old Kepler fall in love with astronomy. Galileo didn’t merely deny that tides were caused by the Moon—he went as far as to mock Kepler’s assertion that they do. “That concept is completely repugnant to my mind,” he wrote—not even in a private letter but in his landmark *Dialogue on the Two Chief World Systems*—scoffing that “though [Kepler] has at his fingertips the motions attributed to the Earth, he has nevertheless lent his ear and his assent to the Moon’s dominion over the waters, to occult properties, and to such puerilities.”

Kepler took particular care with the portion of the allegory he saw as most directly responsible for his mother’s witchcraft trial—the appearance of nine spirits, summoned by the protagonist’s mother. In a footnote, he explained that these symbolize the nine Greek muses. In one of the story’s more cryptic sentences, Kepler wrote of these spirits: “One, particularly friendly to me, most gentle and purest of all, is called forth by twenty-one characters.” In his subsequent defense in footnotes, he explained that the phrase “twenty-one characters” refers to the number of letters used to spell *Astronomia Copernicana*. The friendliest spirit represents Urania—

the ancient Greek muse of astronomy, which Kepler considered the most reliable of the sciences:

Although all the sciences are gentle and harmless in themselves (and on that account they are not those wicked and good-for-nothing spirits with whom witches and fortune-tellers have dealings . . .), this is especially true of astronomy because of the very nature of its subject matter.

When the astronomer William Herschel discovered the seventh planet from the sun a century and a half later, he named it Uranus, after the same muse. Elsewhere in Germany, a young Beethoven heard of the discovery and wondered in the marginalia of one of his compositions: “What will they think of my music on the star of Urania?” Another two centuries later, when Ann Druyan and Carl Sagan compose the Golden Record as a portrait of humanity in sound and image, Beethoven’s Fifth Symphony sails into the cosmos aboard the *Voyager* spacecraft alongside a piece by the composer Laurie Spiegel based on Kepler’s *Harmony of the World*.

Kepler was unambiguous about the broader political intent of his allegory. The year after his mother’s death, he wrote to an astronomer friend:

Would it be a great crime to paint the cyclopien morals of this period in livid colors, but for the sake of caution, to depart from the earth with such writing and secede to the moon?

Isn’t it better, he wonders in another stroke of psychological genius, to illustrate the monstrosity of people’s ignorance by way of the ignorance of imaginary others? He hoped that by seeing the absurdity of the lunar people’s belief that the Moon is the center of the universe, the inhabitants of Earth would have the insight and integrity to question their own conviction of centrality. Three hundred fifty years later, when fifteen prominent poets are asked to contribute a “statement on poetics” for an influential anthology, Denise Levertov—the only woman of the fifteen—would state that

poetry's highest task is "to awaken sleepers by other means than shock." This must have been what Kepler aimed to do with *The Dream*—his serenade to the poetics of science, aimed at awakening.

In December 1629, Kepler funded the printing of his *Dream* manuscript out of his already shallow pocket and set the type by hand himself. The first six pages took him four months, and then his money ran out. He left his family at their temporary home in Sagan and, already in precarious health, traveled to Leipzig, where he borrowed fifty florins—a substantial amount, about as much as a skilled craftsperson made in a year. He then put on his warmest brown stockings, belted a pistol and a powder flask into his tattered black woolen cloak, and made his way to Nuremberg, where he bought a famished mare as bony as himself. The two fragile creatures rode a hundred kilometers through the autumn rain to the Bavarian courts in Regensburg, where Kepler would seek permission to sell some Austrian bonds to repay his debt and finish printing *The Dream*. Days after he arrived and settled into an acquaintance's house, now named after him, Kepler came down with an acute illness. Used to frequent attacks of fever and bodily ailments, he paid little mind. Bloodletting was performed to attempt alleviating the symptoms, but he began slipping in and out of consciousness. Pastors were called in.

At noon on November 15, 1630, Johannes Kepler died, six weeks shy of his fifty-ninth birthday. Three days later, as his body was lowered into a grave in the Lutheran churchyard of St. Peter's Gate, a pastor proclaimed: "Blessed are they who hear and preserve the word of God." The Thirty Years' War, waged unblest and unblest on the alleged word of God, would soon swallow the cemetery and erase any trace of Kepler's bones.

The night after the funeral, a full moon passed through Earth's shadow in a lunar eclipse governed by eternal forces deaf to human words—fundamental truths of nature, which Kepler had spoken in the native tongue of the universe: mathematics. Three hundred thirty-nine years later, his *Dream* would come true as the first human foot stepped onto the Moon, leaping humankind via a trajectory calculated by his laws.

. . .

The Copernican model was the first major idea to challenge our self-importance. The challenge has taken many guises in the centuries since, as new world orders have been introduced—from evolutionary theory to civil rights to marriage equality, which society has initially met with antagonism comparable to that shown by the denizens of Kepler’s hometown. What is at the center—be it of the universe or of our power structures—must stay at the center, even at the cost of truth. “The same, precisely the same conflicts have always stood as now, with slight shifting of scene & costume,” Ralph Waldo Emerson would write in his journal in the middle of the nineteenth century.

Exactly two hundred fifty years after the solar eclipse that first gave Kepler the idea for *The Dream*, a report on the Woman’s Rights Convention of 1852 appeared in the *New York Herald*. Its author—a man who vehemently opposed the idea that women were equal to men—wrote that the convention consisted of “old maids, whose personal charms were never very attractive” and women who have “so much virago in their disposition, that nature appears to have made a mistake in their gender—mannish women like hens that crow.” His op-ed contained this pinnacle of illogic buoyed by emotional hysteria:

If it be true that the female sex are equal to the male in point of physical strength and mental power, how is it that from the beginning of the world to the present time, in all ages, in all countries and climes, in every variety of the human species, the male has been predominant, and the female subject politically, socially, and in the family circle? . . . How did woman first become subject to man as she now is all over the world? By her nature—her sex—just as the negro is and always will be, to the end of time, inferior to the white race, and, therefore, doomed to subjection; but happier than she would be in any other condition, just because it is the law of her nature.

In the wake of his mother’s witchcraft trial, Kepler made another observation centuries ahead of its time, even ahead of the



seventeenth-century French philosopher François Poullain de la Barre's landmark assertion that "the mind has no sex." In Kepler's time, long before the discovery of genetics, it was believed that children bore a resemblance to their mothers, in physiognomy and character, because they were born under the same constellation. But Kepler was keenly aware of how different he and Katharina were as people, how divergent their worldviews and their fates—he, a meek leading scientist about to turn the world over; she, a mercurial, illiterate woman on trial for witchcraft. If the horoscopes he had once drawn for a living did not determine a person's life-path, Kepler couldn't help but wonder what did—here was a scientist in search of causality. A quarter millennium before social psychology existed as a formal field of study, he reasoned that what had gotten his mother into all this trouble in the first place—her ignorant beliefs and behaviors taken for the work of evil spirits, her social marginalization as a widow—was the fact that she had never benefited from the education her son, as a man, had received. In the fourth section of *The Harmony of the World*—his most daring and speculative foray into natural philosophy—Kepler writes in a chapter devoted to "metaphysical, psychological, and astrological" matters:

I know a woman who was born under almost the same aspects, with a temperament which was certainly very restless, but by which she not only has no advantage in book learning (that is not surprising in a woman) but also disturbs the whole of her town, and is the author of her own lamentable misfortune.

In the very next sentence, Kepler identifies the woman in question as his own mother and proceeds to note that she never received the privileges he did. "I was born a man, not a woman," he writes, "a difference in sex which the astrologers seek in vain in the heavens." The difference between the fate of the sexes, Kepler suggests, is not in the heavens but in the earthly construction of gender as a function of culture. It was not his mother's nature that made her ignorant, but the consequences of her social standing in a world that rendered its opportunities for intellectual illumination and self-actualization as fixed as the stars.