Equations from God

Pure Mathematics and Victorian Faith

DANIEL J. COHEN

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INTRODUCTION

The Allure of Pure Mathematics in the Victorian Age

On September 23, 1846, the Berlin astronomer Johann Gottfried Galle scanned the night sky with a telescope and found what he was looking for—the faint light of the planet Neptune. Excitement about the discovery of an eighth planet quickly spread across Europe and America, generating a wave of effusive front-page headlines. Within scientific circles, however, the enthusiasm rapidly soured into a dispute over who should receive credit. Prior to Galle's search, a young British mathematician named John Couch Adams and a well-known French mathematician named Urbain Le Verrier each had prognosticated the size and position of the planet. Unsurprisingly, the debate over credit quickly acquired a fierce, nationalistic overtone. Many British astronomers and mathematicians saw the discovery as an important opportunity to achieve recognition of their growing acumen, embodied in Adams. Across the channel, Le Verrier had the gall to suggest that the scientific academies name the planet after him, and his Gallic colleagues discounted the role of Adams's work in the actual search for the planet.[1]

This divisive argument obscured what was perhaps the more significant aspect of the planetary discovery: Neptune was the first heavenly body found by mathematical prediction. Without peering into the sky at all, Adams and Le Verrier independently calculated the location of the planet through geometrical analysis and the laws of gravitation. Beginning with extremely precise observations of Uranus's orbital irregularities, each mathematician generated a formula for the planet's deviations from a proper ellipse. Meshing Newton's laws with this mathematical description of Uranus's course, they extrapolated outward to the assumed eighth planet, solving the combined equations for Neptune's mass, motion, and distance from the Sun. Aside from the initial observations of anomalous gravitational perturbations in the orbit of Uranus, the discovery of Neptune was an exercise in pure thought.

This remarkable aspect of the discovery was not lost upon contemporaries. To many other scientists—and many nonscientists as well—the work of Adams and Le Verrier signaled a new era of human knowledge, and they loudly sang its praises. Robert Harry Inglis, the president of the British Association for the Advancement of Science, told those convening in the theater of Oxford University on June 23, 1847, that the past year "had been distinguished by a discovery the most remarkable, perhaps, ever made as the result of pure intellect exercised *before* observation, and determining *without* observation the existence and force of a planet; which existence and which force were subsequently verified *by* observation."[2] To determine a truth without the use of the common senses was for Inglis and others a mark of greatness.

John Herschel, the president of the Royal Astronomical Society, proclaimed that the discovery "surpassed, by intelligible and legitimate means, the wildest pretensions of *clairvoyance,*"[3] and wrote that "the movement of the planet had been felt (on paper, mind) with a certainty hardly inferior to ocular demonstration."[4] He further emphasized the universal character of mathematics:

> That a truth so remarkable should have been arrived at by methods so different by two geometers, each proceeding in utter ignorance of what the other was doing, is the clearest and most triumphant proof which could have entered into the imagination of man to conceive, of the complete manner in which the Newtonian law of gravitation stands represented in the formulæ of those great mathematicians who have furnished the means by which alone this inquiry could have been entered on; and how perfect a picture—what a daguerreotype—those formulæ exhibit of its effects down to the least minutiæ![5]

For Herschel, in other words, Adams and Le Verrier had acted as two independent eyes that in tandem produced a binocular, three-dimensional vision of the distant body of Neptune. No less significant was the fact that the two hailed from different countries and different cultures—a true sign of the genius of mathematics. This transnational characterization of the method behind the planetary discovery thus ran counter to the nationalist debate over proper credit. In France, the physicist and mathematician Jean-

Baptiste Biot echoed Herschel's appeal to the universal aspect of such mathematical analysis: "Minds dedicated to the pursuit of science belong, in my eyes, to a common intellectual nation."[6] Transcendental, unifying truth, Herschel and Biot believed, is available to great minds everywhere through the use of mathematics, which disregards all human boundaries.

Some descriptions of the event went even further, characterizing Adams and Le Verrier as potent sorcerers who had conjured and commanded the supreme realm of Truth. In a highly dramatic passage recalling the Romantic poetry of Coleridge and Wordsworth, the Scottish optics researcher David Brewster declared the superiority of these mathematicians over mere observers:

> [The mathematician] calculates at noon, when the stars disappear under a meridian sun. He computes at midnight, when clouds and darkness shroud the heavens; and from within that cerebral dome which has no opening heavenward, and no instrument but the eye of reason, he sees, in the agencies of an unseen planet, upon a planet by him equally unseen, the existence of the agent; and from the direction and amount of its action he computes its magnitude and place. If man ever sees otherwise than by the eye, it is when the clairvoyance of reason, piercing through screens of epidermis and walls of bone, grasps, amid the abstractions of number and quantity, those sublime realities which have eluded the keenest touch, and evaded the sharpest eye.[7]

At work the mathematician becomes a pure spirit, rising out of the confinement of his material body, Brewster conceived. He has no use for everyday faculties like sight, but rather operates with a higher, far more powerful internal sense. This mathematical faculty is not a passive receptor of information, but is instead a penetrating instrument that attains the grandest truths, all of which lie beyond the reach of our five bodily senses.

In the first published book on Neptune, J. P. Nichol, a professor of astronomy at the University of Glasgow, portrayed the discovery in a similarly dramatic way while portraying the mind of the mathematician as in touch with the underlying properties of the universe. Withholding no superlatives, Nichol (although he was not there) recorded the triumphant moment when Le Verrier announced his calculated position of Neptune to the French Academy on August 31, 1846:

> How singular that scene in the Academy! A young man, not yet at life's prime, speaking unfalteringly of the necessities of the most august Forms of Creation—passing onwards where Eye never was, and placing his finger on that precise point of Space in which a grand Orb lay concealed; having been led to its lurking-place by his appreciation of those vast harmonies, which stamp the Universe with a consummate perfection! Never was there accomplished a nobler work, and never a work more nobly done! . . . He trod those dark spaces as Columbus bore himself amid the waste Ocean; even when there was no speck or shadow of aught substantial around the wide Horizon—holding by his conviction in those grand verities, which are not the less real because above sense, and pushing onwards towards his New World![8]

In this histrionic passage, Nichol (like Brewster) demoted the common senses in favor of the higher faculty of mental analysis, which reaches its highest form in pure mathematics. Most mathematicians may seem taciturn, he thought, yet inside they are the true adventurers of the modern age, setting sail for the distant regions of the mind and the universe with powerful ships built from transcendental elements.

The nature of Neptune's unveiling likewise exhilarated William Rowan Hamilton, a prominent Irish mathematician. Indeed, as with Brewster and Nichol, the discovery of the eighth planet so moved him that standard prose seemed woefully inadequate to describe the moment. Instead, Hamilton wrote a poem to honor Adams and astro-mathematical prediction in general. Deeming the weight of Roman mythology to be appropriate to the gravity of his subject, Hamilton compared the ascension of the mathematician to the liberation of the goddess of wisdom:

> When Vulcan cleft the labouring brain of Jove
> With his keen axe, and set Minerva free,
> The unimprisoned Maid, exultingly,
> Bounded aloft, and to the Heaven above
> Turned her clear eyes.[9]

Furthermore, Hamilton emphasized the beneficence of transcendent mathematical discoveries, which come from gifted intellects yet ultimately are not theirs alone. "Having discovered the new planet as a *Truth,*" Hamilton wrote to a friend, "[Adams] has so gracefully disclaimed it as a *Possession.*"[10]

Hamilton's colleague Augustus De Morgan similarly admonished his own corner in the nationalist fight between supporters of Le Verrier and supporters of Adams. "We may wish that the complete honour of this great fact had fallen upon the English philosopher," De Morgan noted, "but far beyond any such merely national feeling is our desire that philosophers should recognise no such distinction among themselves. The petty jealousies of earth are things too poor and mean to carry up amongst the stars."[11] The ecumenical nature of mathematics naturally led to a certain humility, for mathematicians understood that they were unveilers, not creators, of important facts.

Across the ocean, American intellectuals were not far behind in their proclamations about the significance of the planetary discovery. Cyrus Augustus Bartol, the Unitarian pastor of West Church in Boston, echoed the sentiments of his British colleagues in an 1847 article intended for a broad audience fascinated by Neptune:

> [The mathematician] scans these perturbed inclinations more exactly, measures their amount, ascends to their adequate cause, and though that cause still lay darkly ranging on, with to earthly vision undiscernible lustre, he yet predicts its place, and course, and time of arrival into the focus of human sight. His prediction is recorded, to be entertained by some, or incredulously smiled at by others. But lo! in due time the stranger comes as announced, to fulfil this "sure prophetic word" of the divinely inspired understanding of man.[12]

With breathless accolades such as this, Bartol framed the discovery in a decidedly spiritual way. Thus the planetary announcement of 1846 was for men like Herschel, Brewster, Nichol, Hamilton, and Bartol indicative of a new level of human understanding and a new world in which mathematical geniuses such as Adams and Le Verrier were the great communicators of truth.

The irony of this story is that while the prognostication of Neptune may have been an exercise in pure thought, this thought was not entirely rational. Both Adams and Le Verrier used the scientific laws of Newton and geometrical analysis, but they also relied on one completely unscientific theory called Bode's Law.[13] In a manner that recalls Greco-Roman harmonic visions of the universe, this law stated that the distances of the planets from the Sun correspond to the series $4 + 3(2^n)$, if we define the Earth as being

10 units away and use an adjusted first term for Mercury. The heavenly bodies in our solar system should thus be found at the intervals 4, 7, 10, 16, 28, 52, 100, 196, 388, and so on. Why incorporate into one's rigorous calculations this unjustified, ungainly rule, the mention of which is a highly effective way to produce unbridled laughter among twenty-first century astronomers? The two nineteenth-century mathematicians faced the daunting problem that the perturbations in the orbit of Uranus could be caused equally by a small body close to the planet or a large body distant from it, or any size and distance combination in between. Where was Neptune in this enormous spectrum of physical possibility? To help find the needle in the haystack, both Adams and Le Verrier consulted Bode's Law, which was well respected at the time though difficult to square with scientific method. (It is true, however, that the series produced by the law is uncannily accurate for the first seven planets if one includes the asteroid belt as the fifth term.) The rule forecast a planet at a distance of 388 units from the Sun (38.8 astronomical units, or AU, in modern astrophysical terminology), and this number aided the mathematicians in calculating the size (and thus brightness) of Neptune and its position in the sky. As it turns out, Neptune is actually only 30 AU from the Sun (almost a billion miles closer than believed in 1846), and its mass is just one-half of that predicted by Adams and Le Verrier.

Social perception is often more important than reality, however. Many intellectuals saw the discovery of Neptune as a complete and total triumph of the pure thought of mathematics, and this was its true legacy for the next quarter of a century. The eminent American mathematician Benjamin Peirce spoke for many of his colleagues when he reveled in "facts of which the knowledge is wholly mental, and of which there is no direct evidence to the senses," and he saw these facts as "directly known only to the few who have the logical training to follow the argument by which they are demonstrated; and indirectly to those other few who have the loyal faith to trust the testimony of the geometers."[14] The story of Neptune's unveiling illustrates well the manifestation of such idealism in the work and thought of early Victorian mathematicians and scientists. The discovery of Neptune was for J. P. Nichol and his contemporaries an "ever-memorable adventure into that region of pure thought," a transcendent journey into the land of the fundamental ideas of our universe.[15] Praising the ideal nature of the language of mathematics, Nichol highlighted the fact that Le Verrier and Adams had used “the symbols and processes of our most recondite Analysis,” which alone can access invisible, eternal laws.[16]

Such sentiments were obviously more than paeans to mathematics; they were strong professions of a peculiar kind of Victorian faith. As the British astronomer and mathematician Mary Somerville recalled in her autobiography, “Nothing has afforded me so convincing a proof of the unity of the Deity as these purely mental conceptions of numerical and mathematical science which have been by slow degrees vouchsafed to man . . . all of which must have existed in that sublimely omniscient Mind from eternity.”[17] Somerville thought herself extremely lucky to have had a career that dealt daily with the divine forms of pure mathematics. A contemporary of Somerville, the Royal Society fellow Henry Christmas, even argued that the study of mathematics was essential to a complete and rich spiritual life. “He who undertakes to be a missionary of Divine truth, must be a man of enlarged and cultivated faculties,” Christmas wrote in his book *Echoes of the Universe: From the World of Matter and the World of Spirit* (1850), “Now there is one class of study which we wish to recommend as very important . . . and this is the study of mathematics.”[18] For Christmas, the study of mathematics was part of “sanctified learning,” an “intellectual blessing” from God not to be overlooked.[19]

With such intense religious meaning attached to the mathematical prognostication of Neptune, the discipline of mathematics quickly became fodder for sermons. In an 1848 oration, the American Congregational minister Horace Bushnell declared that mathematics clearly consisted of “those pure and incorruptible formulas which already were before the world was, that will be after it, governing throughout all time and space, being, as it were, as integral part of God.”[20] The symbols and correspondences of mathematics thus “put the mathematician in profound communion with the Divine Thought.”[21] Although he was not a mathematician, the religious idealism of his scientific brethren was encouraging to Bushnell. Revelations from the divine sphere comprise the epiphanic moments of science, he believed, as mankind communes with God’s great mathematical laws and concepts. “Geometrical and mathematical truths become the prime sources of scientific inspiration; for these are the pure intellectualities of all created being,” Bushnell proclaimed.[22] At times of discovery the scientist is “raised to a pitch of insight and becomes a seer, entering into things through God’s constitutive ideas, to read them as from God.”[23] Without comprehending the equations of Adams and Le Verrier, Horace Bushnell nevertheless could understand and relay how their work invoked the heavenly realm.

In an 1850s sermon, the Oxford clergyman Adam S. Farrar also diverged from his normal subject matter to inform his audience of the profound significance of pure mathematics. "If any branch of knowledge appeared eminently unlikely to unfold to us any information about God, you would think it would be that system of symbolic formulæ and abstract notions," he noted, "And yet when we apply it to predict the attractions of the heavenly bodies in periods yet to come, it unfolds to us some results of extraordinary grandeur."[24] Farrar therefore concluded that the equations of mathematics ultimately "reveal to us the infinite wisdom of God."[25] "Who can contemplate these amazing results, which manifest the infinite contrivance of the Almighty Architect, without a feeling of devout thankfulness that we have been permitted thus to discover traces of the high and lofty One who inhabiteth eternity!" he declared.[26]

Edward Everett, the New England politician, Harvard administrator, and orator, summarized the feelings of many early Victorian clergymen and mathematicians alike in an 1857 lecture at the inauguration of Washington University in St. Louis. He eloquently announced to the spectators, "In the pure mathematics we contemplate absolute truths, which existed in the Divine Mind before the morning stars sang together, and which will continue to exist there, when the last of their radiant host shall have fallen from heaven."[27] Much of Everett's audience surely nodded in agreement with his lofty assessment of mathematics.

This commingling of the mathematical with the spiritual was not exactly new. Western thought had long given the discipline a lofty spot in the pantheon of knowledge. Indeed, since the height of ancient Greece philosophers have often considered mathematics so sublime that it transcends the profane realm of humanity and ascends into the pure realm of the divine. Chapter 1 traces this link between religion and mathematics in the Western intellectual tradition, concentrating on those thinkers who most frequently appeared in the writings of Victorian mathematicians. Plato's assessment of mathematics, particularly in his later works, created a transcendental aura around the discipline, and Platonists from Proclus onward strengthened this sense of the ideal nature of mathematics. In the early modern period, the Cambridge Neoplatonists firmly established this philosophy of mathematics in the English-speaking world. German philosophical idealism flowing from Immanuel Kant and his English disciples, such as William Wordsworth and Samuel Taylor Coleridge, further prompted mathematicians and intellectuals across the Anglo-American world to subscribe to a transcendental philosophy of mathematics.

Perhaps the most robust form of this mathematical idealism flourished in nineteenth-century America. Chapter 2 focuses on Benjamin Peirce (1809–1880), in many ways the founder of pure mathematics in the United States, and his circle. Peirce, the father of the philosopher Charles Sanders Peirce, was a professor at Harvard for almost a half-century, and was close friends with many of the key intellectual figures of Victorian New England. Living in a land with greater religious latitude—and greater religious intensity—than Great Britain, Peirce expanded upon the sentiments aroused by the discovery of Neptune far more deeply and publicly than his British counterparts. His forthright combination of religious idealism with pure mathematics provides the most vivid picture of this link, and exposes many of the features of nineteenth-century faith that made this combination possible and influential.

Despite Peirce's international renown, however, most of the innovative work in pure mathematics continued to come out of the Old World. Existing mathematical fields diversified and new fields arose in response to significant breakthroughs. The eastern European mathematicians János Bolyai and Nikolai Ivanovich Lobachevsky formulated non-Euclidean geometry, a set of principles counterintuitive to normal human experience that led to a complete redefinition of this most ancient of mathematical pursuits. Mathematics and its associated methodologies also expanded into realms of knowledge other than the natural sciences (where they had been especially at home in physics and astronomy), often through pioneering work by theorists who began their careers as mathematicians but who branched out later in life. At the same time that this move outward occurred, there was a move inward in nineteenth-century mathematics. Concerns about the foundations of the discipline—an interest in the fundamental nature of mathematical knowledge and the process whereby mathematicians come to conclusions—occupied a significant portion of the research agenda.

British interest in the formal aspects of mathematics was particularly apparent in the growing interest in mathematical, or symbolic, logic. As George Boole (1815–1864), one of the founders of mathematical logic and the subject of chapter 3, summarized the nature of this critical field of pure mathematics, it was "not of the mathematics of number and quantity alone, but of mathematics in its larger . . . truer sense, as universal reasoning expressed in symbolical forms."[28] While some of the most famous Victorian mathematicians, such as Arthur Cayley and James Joseph Sylvester, studied and contributed to many of the abundant research topics, the British showed an unusually strong interest in this budding field of symbolic logic. A remarkable three generations furthered the association between British thought and logic while creating a new mathematical field in concert with European counterparts: Boole and Augustus De Morgan (1806–1871), William Stanley Jevons (1832–1885) and John Venn (1834–1923), and Bertrand Russell (1872–1970) and Alfred North Whitehead (1861–1947).

The 1840s and 1850s saw the groundbreaking publication of Boole's *The Mathematical Analysis of Logic, Being an Essay Towards a Calculus of Deductive Reasoning* (1847) and *An Investigation of the Laws of Thought on Which Are Founded the Mathematical Theories of Logic and Probabilities* (1854), as well as De Morgan's *Formal Logic* (1847). Jevons, a student of De Morgan at University College, London, began his career by formulating his own symbolic logic (*Pure Logic,* 1864), which led to his landmark treatise *The Principles of Science* (1874), and he continued to work in the field as he carried its methods into economics and the social sciences in general. Venn expanded upon Boole's theories in two critical texts in the 1880s, *Symbolic Logic* (1881) and *The Principles of Empirical Logic* (1889), in the process inventing the diagrams of overlapping shapes that would come to bear his name. *Principia Mathematica* (1910–1913), in which Russell and Whitehead equated logic and mathematics at the deepest level possible, was a culmination of the innovative mathematical research of the Victorian age. Before this seminal collaboration Russell and Whitehead had independently penned monographs exploring mathematical logic (Russell's *The Principles of Mathematics,* 1903; Whitehead's *A Treatise on Universal Algebra,* 1898). Although far from the totality of British mathematics in the nineteenth century, these were among the most highly influential figures in Victorian mathematical circles.

Why did mathematical logic flourish on the British Isles in the second half of the nineteenth century, and why did British mathematicians pursue this particular region of their discipline with such passion? What motivated the founders of mathematical logic, Boole and De Morgan, and why were promising young British mathematicians eager to embrace and extend their work?

These questions lie at the heart of chapters 3 and 4, which investigate the work and faith of Boole and De Morgan. Historians of mathematics and philosophy, who more frequently provide technical accounts of these disciplines rather than branching out into larger contexts, have continually sought to illuminate the noteworthy differences between the systems of these two British mathematicians.[29] Instead I pose the opposite question: What did Boole and De Morgan have in common that would drive them to create this novel technique? It is apparent, in particular, from unpublished sources, that in the middle decades of the nineteenth century Boole and De Morgan were intensely concerned with interfaith agreement in a chaotic era of belief. It is no coincidence that symbolic logic arose in the wake of Catholic Emancipation, the beginning of Jewish emancipation, and the Oxford Movement. In this extratechnical context, the two mathematicians envisioned their logic based on mathematics as a highly ecumenical endeavor. Although philosophers used symbolic logic in the twentieth century as a way to render spiritual questions irrelevant, in the nineteenth century British intellectuals like Boole and De Morgan used it to rise above sectarian boundaries in the name of a true and universal faith. Thus did antidogmatic and antidoctrinal thinkers attempt to provide a basis for a national, even global, union of believers.

This hidden story of the original symbolic logicians undermines the Whig history of Anglo-American philosophy in the century preceding the First World War. That progressive history chronicles the rise of pure mathematics in the early nineteenth century as the source of a reconsideration of the methods of philosophy.[30] Applying new, rigorous, mathematical tools to the subject of logic, a symbolic system arose that held the promise of a clean, certain, scientific philosophy. Toward the end of the nineteenth century mathematical logic slowly diminished interest in traditional modes of philosophy such as idealism, which philosophers had come to see as nebulous and linguistically problematic. Finally, advances based on Russell and Whitehead's *Principia Mathematica* generated a twentieth-century philosophical school founded on dispassionate calculation, grammar, and proofs rather than poorly defined abstract concepts. Philosophy had finally freed itself from theology and confusion.

As we have already seen, it is wrong to assume that the purpose of nineteenth-century pure mathematics and the symbolic logic that arose out of it was to construct a completely scientific, secular realm of philosophy. Boole and De Morgan did not know what the future would hold, and they had very different agendas than the Whig history imagines. A panoramic examination of their writing—not only their mathematical treatises but also their private letters, unpublished works, and even poetry—makes it clear that the creators of symbolic logic and their supporters yearned for a more profound religion than contemporary sects seemed to offer, a religion that did not have its foundation in dogma, liturgy, or ecclesiastical organizations. Mathematical logic would serve God by providing a way to ascend above such human constructions. It is therefore impossible to discuss the work of such mathematicians without referring to the broader history of the middle of the nineteenth century, especially its religious history.[31]

The link between religious idealism and mathematics apparent at midcentury would become problematic, though, as the Victorian age wore on. Mathematical idealism became threatening to many professionals because it broke down important barriers being erected between religion and science, as well as "high" and "low" strata of thought. To a new generation of mathematicians, religiously tinged mathematics seemed uncomfortably close to the efforts of sectarian clergymen, who well after the discovery of Neptune continued to appropriate mathematical notions to advance religious arguments. A divine vision of mathematics also made it harder for professional mathematicians to distance themselves from amateurs who kept pursuing what the professionals saw as anachronistic problems in pure mathematics, such as circle squaring. That contemporary studies of imaginary numbers, four-dimensional algebras, and infinity readily lent themselves to metaphysical or theological interpretations only made this extraction more difficult.[32]

As fatigue over sectarian strife grew in the 1860s and 1870s, and as the discipline advanced with the founding of professional associations and the modernization of curricula, academic mathematicians pragmatically began to isolate themselves from theology. Caught between his yearning for harmonious interfaith relations and the real world of contentious professional concerns, Augustus De Morgan, for one, diverged from the early Victorian understanding of pure mathematics. By fervently advocating religious ecumenism at the same time that he advanced a secularized, humble philosophy of mathematics, De Morgan found a *via media* that permitted his discipline to flourish professionally without disenchanting the universe. By the end of his life De Morgan pronounced that mathematics was not a language from heaven after all; rather it was simply a highly functional, useful science.

De Morgan's inner turmoil over his beliefs and his work anticipated the tensions and contradictions of the late Victorian era, and his solution forecast the compromise adopted by the next generation of mathematicians. Indeed, this generation began to *belittle* their own endeavor—by making lesser claims about the nature and parameters of mathematics, they secured the discipline from the prying hands of theologians and amateurs, who were drawn to mathematics because of its supposedly transcendental powers. The consternation interlopers such as amateurs and clerics engendered among these later mathematicians was indicative of a new possessive spirit that obscured the religious sentiment of early Victorian mathematics. Some late Victorian mathematicians even began to rebuke colleagues for including theological rhetoric in their publications. The grand idealist philosophy of mathematics faded. Rather than claiming that mathematics transcribed the mind of God, late nineteenth-century mathematicians proffered a baser and more pragmatic vision: mathematics was a set of laws and a system of notation created in the *human* mind.

As chapter 5 details, unlike other disciplines that underwent professionalization in the nineteenth century—medicine, for instance—mathematics was thus seen as grander and more efficacious at the *beginning* of the nineteenth century than at the end. While other Victorian intellectual workers trumpeted the importance and potency of their disciplines in the march to professionalization, many mathematicians counterintuitively advanced more modest philosophies of their branch of knowledge. Intellectual descendents of Boole and De Morgan such as Venn and Jevons moderated the early Victorian enthusiasm that made pure mathematics and symbolic logic spiritual as well as scientific instruments. Symbols and laws that so many intellectuals had once hailed as heavenly were recast by mathematicians as earthly creations.

With the current stereotype of mathematics—dry, abstract, unrelated to larger social concerns—it is easy to forget the earlier divine proclamations about the discipline. Yet the warm-blooded sentiments behind those declarations form an unlikely, but critical, source out of which arose the dispassionate reasoning of modern philosophy and the digital logic at the heart of modern computers. And this story begins with the even earlier beliefs of ancient philosophers such as Plato and strange occultists such as John Dee, whose writings could be found on the bookshelves of countless Victorian mathematicians.

CHAPTER ONE

Heavenly Symbols
Sources of Victorian Mathematical Idealism

I think God's thoughts after him.

—Johannes Kepler

Victorian intellectuals seeking philosophical support for a grand characterization of mathematics did not have to look far afield. One ally was the prominent contemporary philosopher William Whewell (1794–1866), the master of Trinity College, Cambridge, in the 1840s and 1850s.[1] Although Whewell wrote on topics ranging from education, ethics, and the classics, to political economy and literature, he originally made his name in pure mathematics and associated topics in physics.[2] As a young tutor he was an early champion of the Continental system of the calculus, which blossomed among a group of his friends later known as the Cambridge Analytical Society. Whewell's most important work, *The Philosophy of the Inductive Sciences Founded Upon Their History* (1840; 2nd ed. 1847), thus unsurprisingly contained numerous laudatory chapters on pure mathematics. He proclaimed that mathematical notation, concepts, and reasoning were of such great importance that they rightly stood at the head of all "intellectual progress" in the history of mankind.[3]

Although Whewell witnessed and even participated in revolutionary advances in modern mathematics, he nevertheless thought that this lofty understanding of the discipline was as old as Western thought and believed that it was absolutely essential to understand the mathematical conceptions of certain ancient and medieval predecessors. To this end he included long digressions in *The Philosophy of the Inductive Sciences* on critical philosophers such as Plato,[4] and he sprinkled the text with exclamations from the classics that buttressed his own arguments. For instance, Whewell cited the Roman naturalist Pliny the Elder, who declared upon the mathematical prediction of an eclipse, "'Great men! elevated above the common standard of human nature, [have] discover[ed] the laws which celestial occurrences obey.'"[5] In addition to the luminaries of Greco-Roman thought, Whewell included equally long chapters on lesser-known medieval figures such as Ramon Llull.[6] Spaced throughout the history of the West, Whewell portrayed these characters as apostles who sought to spread the gospel of mathematics. The ancient Greek Plato, the Roman Pliny, and the medieval Spaniard Llull had all come to the same conclusion, though separated by the centuries—they looked upon mathematics as a discipline that communed with the highest elements of the cosmos. To them, mathematics was neither a vocation nor an avocation; rather, it was a calling.

Like Whewell, other Victorian mathematical idealists looked to these older sources for intellectual support, justification, and inspiration. Indeed, mid-nineteenth-century British and American mathematicians, especially those interested in pure mathematics, had an unusually strong sense of the history of their discipline. Simply put, they were fanatical bibliophiles. Their keen interest in the portrayal of mathematics through the ages was apparent in the rare tomes on their bookshelves and in the importance they gave to the conceptualization of mathematics above and beyond proofs and formulas. Augustus De Morgan could have been mistaken for a librarian; the list he compiled of ancient, medieval, and Renaissance mathematics books remains a useful bibliography. De Morgan also wrote biographies of premodern mathematicians for a number of encyclopedias. Similarly, John Herschel recounted the ideas of ancient Greece in a monograph for the *Cabinet Cyclopædia*.[7] George Boole and the American educator Thomas Hill (a central figure in chapter 2) both cited the Renaissance Neoplatonist John Dee as a crucial antecedent to their own thought.[8] William Rowan Hamilton went so far as to read Plato in the original Greek, and connected his own theories to Pythagorean conceptions that had influenced Plato.[9]

Because these Victorian mathematicians saw their work as the culmination of a lengthy and privileged Western intellectual lineage, the contents of their personal libraries provide an extremely useful entrée into the Anglo-American ideology of mathematics in the early nineteenth century. In these volumes, ancient, medieval, and early modern philosophers and mathematicians posited a universe divided into two planes—the sacred realm of the ideal and the profane realm of matter—with mathematics as a courier between the two. The discipline was in a unique position: available to great minds in this world, yet part of the invisible, divine sphere. Like the Victorians, many of the authors of these works yearned to transcend the fault lines of their age through mathematics.

Plato, Platonism, and Mathematics

Alfred North Whitehead may have been oversimplifying slightly when he characterized European thought as "a series of footnotes to Plato," but many of his predecessors in pure mathematics would have undoubtedly concurred. As far as we can tell, the Pythagoreans maintained a mystical belief in the power of mathematics and its symbols, but Plato and his disciples were the first to proffer a coherent, persuasive, and lasting vision of mathematics as a transcendental tool of an elite clerisy. The Victorian fathers of pure mathematics avidly read Plato, mathematically oriented Platonists such as Proclus, and British Neoplatonists of the early modern period, and they incorporated the Platonic characterization of mathematics and mathematical symbols into their own philosophies.

Although most often read as a treatise on political order, Plato's *Republic* also expounded on the special nature and potency of mathematics, and Victorian mathematicians focused on these lesser-known passages to support a transcendental definition of their discipline. Plato's advocacy of mathematics is most pronounced in Book 7, in which he described the proper education for the philosopher-kings of his ideal city. Raising the issue of exactly which topics these leaders should study to orient their minds toward the realm of the ideal Forms, Plato advocated a central role for those disciplines that "are wholly concerned with number" because "they appear to lead one to the truth."[10] Moreover, philosopher-kings should not merely dabble in the art of mathematics, but rather invest themselves wholeheartedly in the pursuit: "We should legislate and persuade those who will share the highest offices in our city to turn to arithmetic and to pursue it in no amateur spirit, but until they reach by pure thought the contemplation of the nature of numbers." Specific numbers or individual geometric shapes do not matter in and of themselves; the goal should be a higher mental state attainable through mathematics. After all, Plato's leaders employ mathematics for the greatest ends, not the mundane necessities of everyday life: "They do not pursue this study for the sake of buying and selling like merchants and retailers, but both for the sake of war and to attain ease in turning the soul itself from the world of becoming to truth and reality."[11] Thus Plato elevated mathematics to a high position in his utopia by characterizing the discipline as a "bond" (*desmos*) between this world and the ideal plane. As the character Socrates rhapsodizes about geometry to Glaucon in the *Republic,* "[It] is knowledge of that which exists forever. It would then, my noble friend, draw the soul toward truth and produce philosophic thought, and make us direct upward those parts of ourselves which we now direct downward when we should not."[12] Mathematics was a method of reasoning that resonated with the transcendental realm of Truth.

However, Victorians interested in reasserting Plato's grand estimation of mathematics, like other appropriators of Plato's authority, had to ignore certain contradictory passages in the *Republic*. Mathematics may be used to lead human beings to the ideal realm, the middle-aged Plato of the *Republic* believed, but he also cautioned against confusing the discipline with the highest participation in the Forms or the Forms themselves. For instance, in Book 6, Plato specifically placed mathematics in the *second*-highest category of human intelligence, *dianoia* (reasoning). Just above this category is the more important *noesis,* or understanding, in which human beings directly engage the realm of the Forms.[13] Since Plato stated in the *Republic* that mathematics was one of the "*preliminary* studies which must precede the dialectic,"[14] and because of his ultimate characterization of *philosophos* as higher than *mathematikos,* the idealist mathematicians of the nineteenth century had to turn to Plato's later works for more unqualified support of the transcendental conception of mathematics.

Like many intellectuals, Plato became more concerned with the spiritual as he neared the end of his life, and in his later work his proclamations regarding mathematics became less cautious and reserved. This is especially true in the *Timaeus,* with its analysis of the universe in terms of a divine and harmonious geometry. In his description of the "world-soul," Plato used mathematics extensively, showing how exact numerical principles divided the cosmos.[15] In fact, Plato believed that at every stage of the creation, from the marking of the boundaries between elements to the paths of the heavenly bodies, the Demiurge impressed upon the universe geometry and harmonic multiples.[16] To understand the true nature of the cosmos, philosophers must therefore comprehend basic mathematical principles. And when engaging in the mathematical analysis of the universe, the human soul achieves a resonance with its fundamental composition. Given this exceedingly divine conception of mathematics, a well-thumbed copy of Plato's *Timaeus* unsurprisingly could be found on the shelves of many high-minded nineteenth-century mathematicians and astronomers.[17]

An even more significant text for these Victorians, however, was a more obscure work of Plato's, the *Epinomis*. Quotations from the *Epinomis* (in Greek) often graced the title pages of grade-school math primers in the early Victorian era. Although now the *Epinomis* is only infrequently read (and frequently puzzled over), two centuries ago many intellectuals and mathematicians considered it to be an essential addendum to the all-important *Laws*—that is, the answer key to one of Plato's grandest textbooks.[18] In the twelfth and final book of the *Laws,* Plato tantalized his audience with a question posed to the members of the Nocturnal Council: How can one become supremely virtuous and satisfied? Or as he rephrased this critical inquiry at the beginning of the *Epinomis,* "What are the studies which will lead a mortal man to wisdom?"[19]

With a greater emphasis than in the *Republic,* Plato stated in the *Epinomis* that mathematics was the way to the ultimate comprehension of the universe, and that mathematical notation bridged the gap between the realm of the Forms and the physical world. Anticipating Galileo's famous dictum that God wrote the book of the universe in the language of mathematics, Plato asserted that the Demiurge "constructed us with this faculty of understanding what is shown us, and then showed us the scene He still continues to show."[20] The ability to reason mathematically was thus a sublime present from God: "With the gift of the whole number-series, so we shall assume, [the Demiurge] gives us likewise the rest of understanding and all other good things. But this is the greatest boon of all, if a man will accept his gift of number and let his mind expatiate over the whole heavenly circuit."[21] Furthermore, mathematics functions as the divine queen of the disciplines, without which all knowledge would falter: "There is every necessity for number as a foundation . . . we shall also be right if we say of the work of all the other arts which we recently enumerated, when we permitted their existence, that nothing of it all is left, all is utterly evacuated, if the art of number is destroyed."[22] In his starkest assessment of man's attempt to understand the cosmos and reach a higher state of existence, Plato claimed in the *Epinomis,* "If number were banished from mankind, we could never become wise at all."[23] One can hardly imagine a stronger assertion: Without mathematics—that God-given way of illuminating the universe—human beings would flounder in the dark.

The overriding concern with mathematics in the *Epinomis* (apparently surpassing the importance of *noesis* in his earlier work) has struck many Plato scholars as somewhat discordant with the rest of Plato's corpus; some even believe it is pseudo-Platonic.[24] This criticism seems to ignore the *Timaeus,* an accepted text, which appears to present an inchoate version of the characterization of mathematics in the *Epinomis*. However, just as the use of Bode's Law did little to taint the discovery of Neptune, the minor detail of who actually wrote the *Epinomis* mattered little to nineteenth-century mathematical idealists. They would repeatedly invoke the work to support their ideology, and would reiterate its arguments, often verbatim, in their own writings. They reveled in Plato's declaration that mathematics was a—or even *the*—divine language. Moreover, in a less high-minded way many mathematicians also concurred with Plato's belief that only a few thinkers could ascend to the transcendental state mathematical contemplation and notation promised. The "science of number" was difficult to learn and even more difficult to master, and therefore the blissful realm of profound understanding was unattainable for humanity "with the exception of a chosen few," as the *Epinomis* concluded.[25]

Plato's grander statements about the nature of mathematics perhaps would have drifted into obscurity had they not been highlighted centuries after his death by the Hellenic philosopher Proclus (ca. 410–485). Proclus wrote shrewd commentaries on Plato's mathematical works, as well as on Euclid's *Elements*. In 1789 the English philologist Thomas Taylor (a Platonist in his own right) published a translation of that latter commentary, a seminal treatise on the philosophy of mathematics, under the title *The Philosophical and Mathematical Commentaries of Proclus on the First Book of Euclid's Elements,* which became a popular reference for nineteenth-century pure mathematicians.[26] Proclus's universe, based on Plato's idealist thought, was a bifurcated one. Human beings exist in a cave of impaired perception, a profane realm of limited, imperfect things: matter, decay, ever-changing shapes. Above our muddled existence, however, is another, divine realm, a sphere of purity and eternal Truth. Mathematics plays a special role in this divided universe—it ascends from the world of impermanence to this higher, heavenly plane.

This characterization of mathematics as a courier between the sacred and the profane, clearly appropriated from Plato, became a hallmark of Procline Neoplatonism.[27] The very first line of Proclus's *Commentaries* asserted that mathematics was a unique intermediary: "Mathematical being necessarily belongs neither among the first nor among the last and least simple kinds of being, but occupies the middle ground between the partless realities [the Forms, or *Nous*] and divisible things characterized by every variety of composition and differentiation."[28] On the one hand, the highest mathematical concepts "stand in the vestibule of the primary forms, announcing their unitary and undivided and generative reality."[29] Since we human beings can use them in a practical way, however, mathematical concepts clearly "have not risen above the particularity and compositeness of ideas and the reality that belongs to likenesses."[30] In short, because of its participation in both the perfect and imperfect spheres of existence, mathematics provides a mental pathway for ascending out of the material realm and attaining an ideal comprehension of the universe. Proclus's succinct definition of mathematics as the "recollection of the eternal ideas in the soul" strikingly portrayed the ultimate purpose of the discipline.[31] At the end of the prologue to the *Commentaries,* he summarized the tremendous potency and spiritual role of mathematics:

> It arouses our innate knowledge, awakens our intellect, purges our understanding, brings to light the concepts that belong essentially to us, takes away the forgetfulness and ignorance that we have from birth, sets us free from the bonds of unreason; and all this by the favor of the god who is truly the patron of this science, who brings our intellectual endowments to light, fills everything with divine reason, moves our souls towards *Nous* [the Forms], awakens us as it were from our heavy slumber, through our searching turns us back upon ourselves, through our birthpangs perfects us, and through the discovery of pure *Nous* leads us to the blessed life.[32]

Irrationality, clouded perception, and faulty notions accumulated throughout our lifetimes obscure our vision of the truth, Proclus thought, and condemn us to the flickering shadows of Plato's cave. Thrown down from heaven, mathematics is the lightening bolt that rouses us, dispelling the darkness of the cave with an unparalleled and sublime brilliance that alerts us to the possibility of seeing everything in such a vivid, penetrating light. The mathematical arts thus involve nothing less than the purification and ascendancy of the human soul, permitting it to overcome the innate imperfection of mankind and the human senses. Placing our trust in that which lies "between absolutely indivisible realities and the divisible things that come to be in the world of matter" finally allows us to exit the cave.[33]

Beginning in the sixteenth century Procline Neoplatonism returned to prominence in Western thought.[34] In the intellectual setting of early modern Britain, mathematics became the stronghold for this idealism, as opposed to on the Continent, where Neoplatonism's main influence occurred in philosophy.[35] Victorian mathematicians looking to promote a grand vision of their discipline could therefore appeal to a robust homegrown tradition.

Preeminent among the foundational mathematical texts in the early modern period was a famous printing of the ancient work that had entranced Proclus: the 1570 English edition of Euclid's *Elements*. The book was notable not only for its fine illustrations and accomplished translation but also for its preface by John Dee (1527–1608), a prominent Elizabethan mathematician. Dee, like many heroes of later mathematicians such as George Boole, Augustus De Morgan, and Benjamin Peirce, led a colorful existence. In addition to his mathematical endeavors, he was an astrologer, alchemist, secret agent, and friend of Queen Elizabeth.

He was also perhaps the last representative of a long and influential line of Renaissance Neoplatonists. These intellectuals strove in myriad ways to discover how one could rise above the profane, physical world and commune with the divine realm of spirit. They also, of course, carefully read the later works of Plato. On the shelves of Dee's enormous private library (which was almost ten times larger than the collection at the University Library of Cambridge), he tellingly kept not one, but at least four, copies of Plato's *Timaeus*. Marsilio Ficino, the Renaissance philosopher and physician who translated Plato into Latin, summarized the legacy of works such as the *Timaeus:* "The soul contemplating the divine things assiduously and intently grows up so much on food of this kind and becomes so powerful, that it overreaches its body above what the corporeal nature can endure."[36] Ficino believed this transcendental state would lead to an absolute understanding of the universe, and thus the ability to manipulate it in magical ways.

John Dee inherited this occult quest and was convinced that mathematics was the special language that would transport its conjurer to that higher plane of divine truth. Dee's introduction to Euclid's *Elements* encapsulated the purpose and efficacy of mathematics in a manner that resonated with the mathematical idealism of the early Victorian age; Boole later called the introduction "very fruitful" and other mathematicians repeatedly cited it.[37] In a way by now familiar, Dee divided all things in the universe into three categories: the natural, the supernatural, and the mathematical. Natural things are perceivable, changeable, and divisible. Supernatural things are invisible, immutable, and indivisible. Mathematical concepts occupy a critical middle position between the natural and the supernatural, thus mediating between these realms:

> Surmountyng the imperfectió of conjecture, weenyng and opinion: and commyng short of high intellectuall cóceptió, are the Mercurial fruite of *Dianœticall* discourse, in perfect imagination subsistyng. A mervaylous newtralitie have these thinges *Mathematicall,* and also a straunge participatió betwene thinges supernaturall, immortall, intellectual, simple and indivisible: and thynges naturall, morall, sensible, compounded and divisible.[38]

Once again the fundamental definition of mathematics as simultaneously of the ideal and material spheres is apparent. Dee's conception of its "newtralitie" is also critical—mathematical analysis leads to transcendental truth untainted by the infirmities of human thought. "In Mathematicall reasonings, a probable Argument, in nothyng regarded: nor yet the testimony of sense, any whit credited: But onely a perfect demonstration, of truthes certaine, necessary, and invincible: universally and necessaryly concluded: is allowed as sufficient for an Argument exactly and purely Mathematicall," he concluded.[39] Exactly three hundred years after Dee's edition of Euclid's *Elements,* Benjamin Peirce would win acclaim among contemporaries by echoing the Elizabethan in his definition of mathematics as "the science which draws necessary conclusions."[40] For both the nineteenth-century mathematician and his sixteenth-century predecessor, the concept of "necessity" was infused with Platonic meaning—absolute declarations require communication with the pure realm of the Forms.

Further inspiring Victorian idealists such as Peirce, John Dee envisioned mathematics as more than just the path to certainty—studying it deeply was a spiritual pilgrimage as well. Pure mathematicians commune with heaven. In his preface to Euclid's *Elements,* Dee borrowed liberally from Plato's *Timaeus* in his description of the nature of the cosmos: "All thinges (which from the very first originall being of thinges, have bene framed and made) do appeare to be Formed by the reason of Numbers. For this was the principall example or patterne in the minde of the Creator." For Dee, therefore, the ability to use mathematics was a great revelatory gift from God to mankind. He optimistically declared that mathematics not only allows us to come to certain answers, but lets us "clime, ascend, and mount up (with

Speculative winges) in spirit, to behold in the Glas of Creation, the *Forme* of *Formes* . . . searchyng out and understandyng of every thyng, hable to be knowen."[41] Dee's Platonic conception of mathematics as a mediator between the natural and supernatural made the discipline essentially a religious endeavor.

In addition to Dee, the English Neoplatonist philosopher John Norris (1657–1711), a contemporary of Newton, greatly influenced the mathematical idealists of the nineteenth century. Sometimes called "the English Nicolas de Malebranche," Norris was in fact deeply indebted to that French idealist thinker, as well as to the Cambridge Neoplatonists Henry More and Ralph Cudworth.[42] Significantly, he was also the first philosopher to use Platonist arguments to attack John Locke's emphasis on the senses and the limitations of what we can know. Like Plato and John Dee, Norris broke the universe into two realms, which he called the "Ideal" and the "Natural." In his most significant work, *An Essay Towards the Theory of the Ideal or Intelligible World* (2 vols., 1701–1704), Norris asserted that the human mind, though perhaps limited, has methods to bridge these two realms and thus engage the spiritual plane. Foremost among these methods was mathematics, which Norris used as a case in point against Locke's phenomenalism. Mathematics, Norris claimed, was at heart the use of divine and eternal concepts in the analysis of the natural world; it consisted of ideas which "must have their Foundation in an Eternal Mind."[43] Indeed, mathematics lifts us up to God's "Ideal World." Norris assailed Locke's argument that mathematics relies on physical diagrams that come from the senses: "I see Mathematic Figures as they are in Idea, because I see them in such Perfection and according to such a state of Immutability as they have not in Nature . . . So that tho' the Natural World be the object of *Sense,* yet the Ideal World is the proper object of *Knowledge*."[44] Any science (in the original, broad sense of the word) that relies on mathematics therefore leads to the realm of "Eternal Essences."[45] One obvious corollary to this philosophy is that the pursuit of mathematical knowledge could be the basis of a rich spiritual life removed from cathedrals or priests. For Victorian mathematicians who felt uneasy with the Church yet who wanted to remain active in their faith, this association of religious devotion with the discipline of mathematics proved extremely appealing.

A final early modern English Neoplatonist to have a significant impact on the work of mathematical idealists in the nineteenth century was the algebraist and cofounder of the Royal Society, John Wallis (1616–1703).[46]

Augustus De Morgan had a particular interest in Wallis, owning his works in their original editions, authoring the *Penny Cyclopedia* biography of him, and highlighting the importance of the seventeenth-century mathematician to George Boole.[47] Wallis was an iconoclast like John Dee. Besides being a mathematician, logician, and grammarian, he was adept at deciphering codes and was instrumental in the decoding of Royalist letters and papers during the Civil War.

The significance of Wallis's work for the Victorians was his extension of the transcendental philosophy of mathematics into the subfield of algebra. Wallis's seminal monographs in this area, *Mathesis Universalis* (1657) and *Treatise of Algebra* (1685), reconsidered what mathematical symbols actually signify. Rather than restricting algebraic letters to their traditional role as surrogates for numbers, Wallis argued (in a manifestly Platonic fashion) that algebra was in fact a "Universal Art," a discipline with far more potency than mathematicians or others generally conceived. For Wallis, algebra was a science consisting not of mere signifiers (i.e., of numbers), but of symbols that were abstract, ideal objects.[48] "The great Advantage of Algebra," he claimed, was "that it manageth Proportions abstractly, and not as restrained to Lines, Figures or any such particular subject; yet so as to be applicable to any of these particulars as there is occasion."[49] This reconceptualization of the letters and marks used in mathematics prompted nineteenth-century pure mathematicians to investigate a wider range of uses for their discipline. In De Morgan's *Encyclopaedia Britannica* article on the history of mathematics he was not kind to Descartes or the Italian algebraists, yet he defended John Wallis's work as being of special merit.[50]

Antecedents of Mathematical Logic

One important use for Wallis's broader sense of pure algebra was in the service of linguistic clarity. Given the long Platonic tradition in the philosophy of mathematics, it should not come as a surprise that a critical field of modern pure mathematics—mathematical logic—had premodern antecedents, and the Victorians were well aware of them. Although commonplace today, the replacement of words and concepts with algebraic symbols was not a self-apparent idea. With their urge to transcend the divisions and disarray of human culture for the unity of the divine plane, medieval and early modern precursors gave the nineteenth-century founders of mathematical logic a basic conceptual framework. Their systems varied significantly from the logic of Boole or De Morgan, yet they shared a common motivation: to reconstruct the heaven-reaching Tower of Babel—this time without being thwarted by the confusion of tongues.

Ramon Llull (occasionally spelled Lull or Lully; 1232–c.1316) was the first, and one of the most frequently mentioned, progenitors of symbolic substitution.[51] For the first thirty years of Llull's life he was a pompous courtier and poet in the court of the King of Aragon, Jacob, on the Iberian peninsula. However, upon observing frightful skin lesions on the woman he adored, he gave up the life of the court and entered a monastery.[52] There, he solemnly and assiduously studied logic for the remainder of his life, arriving at a definition of the discipline that would resonate in the nineteenth century: "Logic is the art and science by means of which truth and untruth can be recognized by reason and separated from each other—the science of finding truth and eliminating falseness."[53] Yet Llull, a devout Christian and occultist, was anything but a modern secular philosopher. Logic held promise as a technique for unveiling divine truth, he believed, and thus could be a potent ecclesiastical tool. Llull conceived of his own logical system as a way for the Christian Church to approach infallibility in its understanding of the world. By extension, he also thought that his undertaking would be highly valuable in converting Jews and Muslims to the Christian faith. Llull believed that his logic could bring an end to the religious divisions of the world by appealing to a supremely efficacious, divine Christian Art.

Llull borrowed heavily from Platonic and Neoplatonic sources to create his complex system. He based his method primarily upon symbolism, and saw his notation as coming from a supernatural source, infused with the absolute power of God's domain. Llull's "Alphabet," which employed letters for specific divine attributes, embodied this idea. He substituted the letter *B* for "Goodness," *C* for "Magnitude," *D* for "Eternity," *E* for "Power," *F* for "Wisdom," *G* for "Will," *H* for "Strength," *I* for "Truth," and *K* for "Glory." At times he added or subtracted other symbols and letters. Llull's technique, simultaneously redolent of mathematics, astrology, and roulette, placed these symbols on rotating wheels that brought them into complex geometrical relationships with each other. The operating *magus* interpreted the resulting patterns.

Though obviously far from today's symbolic logic, some aspects of Llull's system—especially when viewed from his perspective—clearly prefigured modern efforts: the replacement of words by symbols; the manipulation of those symbols by a rigid set of rules; the acceptance of the end product of that manipulation as absolutely true because of the “rigor” of the technique. More directly significant for Victorian mathematical logicians than these perhaps tenuous links, however, was the fact that Llull’s system required him to meditate on the logical meanings of “and” and “or,” a critical first step toward any symbolic logic.[54] Clearly a great many differences separate Ramon Llull’s *Tractatus Novus de Astronomia* from the *Principia Mathematica* of Bertrand Russell and Alfred North Whitehead. Nevertheless, as Francis Yates and others have discovered, Gottfried Leibniz had Llull’s “Art” at least partly in mind when he was constructing the theoretical foundations of mathematical logic.[55] As another indication of Llull’s importance, John Dee’s collection of the medieval logician’s manuscripts was larger than his stock of any other author’s.[56]

Early modern British mathematicians were somewhat less ambitious than Llull, yet they too yearned for a transcendental symbolic technique. One central figure in this quest was Thomas Harriot (1560–1621), a precursor often on the lips and in the minds of nineteenth-century pure mathematicians. Harriot was a pioneer in many respects: a geographer on the second expedition to Virginia in 1585, a religious nonconformist who denied the divinity of the Old Testament, and a mathematical innovator of the first order. He believed fervently in the existence of imaginary numbers, a bold position for his age, and was responsible for creating the comparison symbols “>” and “<”. Like Llull, Harriot created a rudimentary symbolic system based on a set of fundamental laws. Utilizing algebraic notation he tried to create a new phonetic alphabet that would, in a sense, express all languages. Although some scholars have detected a Cabalistic streak in Harriot’s project,[57] his goal seems to have been decidedly less mystical; Harriot was mostly interested in using his system to record and decipher the languages of New World natives.[58] Regardless of his actual intention, Victorian mathematicians saw Thomas Harriot as another prominent forefather of the reduction of language to a mathematical format, and it was this particular element of his wide-ranging work that fascinated them. Augustus De Morgan was especially intrigued by Harriot’s system (and his liberal theology), writing about him to interested colleagues such as John Herschel.[59]

The early modern system most germane to the mathematical logic created in the Victorian age was the symbolic theory of the mathematician and Bishop of Chester, John Wilkins (1614–1672). Wilkins, a founding member of the Royal Society, was another historical favorite of nineteenth-century pure mathematicians. In his monograph *An Essay Towards a Real Character, and a Philosophical Language* (1668), he attempted to create a new dialect based on symbols that would rise above the uncertainties and inconsistencies of normal speech. In a phrase strikingly reminiscent of the work of the Victorian mathematical logicians, Wilkins sought "the distinct expression of all things and notions that fall under discourse."[60] His contemporary Thomas Hobbes had tried to do much the same thing in the first book of his *Leviathan* (1651), but Wilkins's project was far greater in scope and more removed from words themselves.

Profoundly distraught that the manifold languages of humanity contained innate deficiencies and generated widespread confusion, Wilkins believed that he could reduce them all to a set of basic laws. "Abstracting from many unnecessary rules belonging to instituted languages," as he put it, he set about constructing a series of tables that would encapsulate the fundamental relationships used in communication.[61] From these tables Wilkins then went about the Herculean task of distilling the entire dictionary into a succinct format, hoping to arrive at a kind of *ur*-language. Ultimately, he thought he could transcend the long, inefficient words of the vernacular with an ideal language consisting of an assortment of marks similar to those used in mathematics. These symbols, Wilkins believed, were far clearer than words: "If every thing and notion had a distinct mark, with some provision to express grammatical derivations and inflections, it would answer one great end of a real character, to signify things and not words."[62] For Wilkins, symbols were akin to crystalline Platonic Forms; unlike words, they were not multivalent and thus they provided a secure foundation for rational discussion and deliberation.

The Victorians who founded modern mathematical logic may have judged John Wilkins's system defective, but they clearly emulated his basic idea and strongly agreed with the motivation behind it. They envisioned their century like the seventeenth century—an era with a high potential for sectarian strife. And like Wilkins, mathematicians such as Boole and De Morgan sought ways to rise above such divisiveness. This ecumenical streak ran through the technical marks and tables of *An Essay Towards a Real Character, and a Philosophical Language*. "The advantages proposed by this philosophical language," Wilkins wrote, "[are] the facilitating of mutual commerce among the several nations of the world; the improving of natural knowledge; and the propagation of religion." In a passage that would resonate in the nineteenth century, Wilkins prophesied the broad application and power of his method, especially in the service of faith:

> It might contribute much to the clearing of some modern differences in religion, by unmasking many wild errors that shelter themselves under the disguise of affected phrases: which being philosophically unfolded, and rendered according to the genuine and natural importance of words, would appear to be inconsistencies and contradictions; and several of these pretended mysterious profound notions, expressed in big swelling words, by which men set up for reputation, being this way examined, would either appear to be nonsense, or very jejune.[63]

Words can lie, distract, mislead, confuse, and advance false religion; clean notation, exemplified in the symbols of mathematics, cannot.

Although they worked in a putatively technical and forward-looking discipline, by looking back to figures such as John Wilkins, early Victorian mathematical logicians saw themselves as providing a means for the resolution of seemingly intractable cultural and religious problems. Nineteenth-century mathematical logic, like Wilkins's algebraic dialect of the seventeenth century, would, in Wilkins's words, hopefully "prove the shortest and plainest way for the attainment of real knowledge, that had yet been offered to the world."[64] A new language, based on the ideal nature of mathematics, would purify and elevate the profane world.

Indeed, the power to rise above the mire of innumerable languages and opinions became a potent theme in pure mathematical research in the Victorian era. As John Herschel lamented just before George Boole and Augustus De Morgan began to develop this new logic, "It is, in fact, in [the] double or incomplete sense of words that we must look for the origin of a very large portion of the errors into which we fall."[65] What was the best way out of this predicament? Herschel, like Plato, had a clear idea of the direction to take:

> The study of the abstract sciences, such as arithmetic, geometry, algebra . . . being free from these sources of error and mistake, accustom us to the strict use of language as an instrument of reason, and by familiarising us in our progress towards truth to walk uprightly and straight-forward on firm ground, give us that proper and dignified car-

> riage of mind which could never be acquired by having always to pick our steps among obstructions and loose fragments, or to steady them in the reeling tempest of conflicting meanings.[66]

Simplification and clarification of discourse through the transcendental reasoning and symbols of mathematics appeared to be a traditionally sanctioned solution to a difficult problem. As the poet William Wordsworth put it, his contemporaries must condemn "that false secondary power / by which we multiply distinctions, then / Deem that our puny boundaries are things / That we perceive, and not that we have made."[67] The fathers of mathematical logic followed Herschel and Wordsworth in their search for truth that originates above such groundless human classifications.

Modern Idealism and Romanticism

Ancient, medieval, and early modern thinkers who advanced mathematical Platonism might have remained historical curiosities were it not for the boost given to philosophical idealism in the late eighteenth and early nineteenth centuries. The decades following the French Revolution were a time of political, cultural, and religious turmoil that rekindled a strong interest in transcendental notions among intellectuals. By describing the universe as split between the "phenomenal" and "noumenal" realms—that is, between the realm of physical matter, space, and time, and the atemporal and nonspatial realm inhabited by "things-in-themselves," God, and the human soul—Immanuel Kant, in particular, inaugurated a robust period of philosophical idealism in Europe and America. Kant's philosophy naturally engendered a strong desire to understand how human beings could access the elusive noumenal realm. He postulated that this communion occurred through a special faculty of the mind—a transcendental form of reason, as opposed to the speculative reason that analyzes the material realm. Filtered through the British Romantics, Kant's twin concepts of the noumenal realm and transcendental reason provided a theoretical framework for the lofty construction of pure mathematics in the Victorian era.

Finding support for the divinity of mathematics in Kant's philosophy required a myopic and somewhat distorted view of his thought, however.[68] It all depended on which part of his definition of mathematics one chose to emphasize. Kant held that mathematics was "synthetic a priori" knowledge;

"synthetic" meaning it could add to our storehouse of information, and "a priori" indicating it did not come from the experience of the senses. When Kant expanded on the first part of the definition, "synthetic," he seemed hesitant to characterize mathematics as genuinely transcendental. In these passages he indicated that pure mathematics was humanly constructed, rather than eternally present in the noumenal realm. In the *Critique of Pure Reason,* for example, Kant concluded that higher-order mathematical laws "contain an arbitrary synthesis."[69] We establish basic mathematical definitions and rules in our mind and then proceed to combine them to generate more complex definitions and rules. Although mathematics does not have its origin in the physical world, Kant appeared to be arguing, its laws do not originate in the transcendental realm either.

Nevertheless, Victorian mathematical idealists lauded Kant for removing their discipline from the province of mere speculative reason based on the impressions of the senses. As the tide of Cambridge Neoplatonism ebbed in the late seventeenth century, many seminal British thinkers, including John Locke and David Hume, came to perceive mathematics as a refinement of everyday sensory analysis. All mathematical facts were a posteriori knowledge, gained from mundane tasks such as the measuring of physical objects. Kant's fervent belief that mathematics was a priori knowledge, in contradistinction to such materialistic characterizations, thus carried significant weight. The mathematical law that parallel lines never meet is impossible to attain from experience (since lines are infinite in length), Kant noted, yet it is an important fact of (Euclidean) geometry, and it leads to other profound insights. With examples such as this, Kant used mathematics to highlight how human beings could acquire grand ideas without the senses.

Furthermore, Kantian idealism meshed well with older Platonic sources, combining to give the discipline of mathematics an air of clairvoyance. Thinkers such as Proclus, Dee, Norris, and Wallis told Victorian mathematical idealists what many wanted to hear in concert with Kant's philosophy: mathematics was the great mental faculty that would allow human beings to gain access to the invisible kingdom of Absolutes. Just as Kant's cautious statements about the noumenal realm were ignored by countless idealists in the nineteenth century, so were his less grandiose passages about mathematics ignored by those interested in giving the discipline a heavenly pedigree. It would take just a few small nudges to move mathematics entirely into the noumenal realm.

Samuel Taylor Coleridge (1772–1834), the Romantic poet and wholesale importer of German philosophy into the English-speaking world, was one of those who prodded the philosophy of mathematics in the direction of the divine. His strong Neoplatonic streak, along with his reading of Kant, Schelling, and the *Naturphilosophen,* helped push Anglo-American thought away from its focus on the world of matter.[70] Like John Norris, Coleridge wished to salvage a higher view of the universe from contemporaries who, he believed, improperly concentrated on the base and particular. By highlighting the ability of the human mind to transcend the deterministic causal chain of the phenomenal realm, Coleridge was largely responsible for reinvigorating philosophical idealism at the beginning of the Victorian age. Furthermore, while he spurred countless English-speaking writers and artists to seek the noumenal realm, his influence was not restricted to those in the humanities. Mathematicians, too, became more interested in the ideal realm after reading Coleridge.

Appropriating Kant's conception of transcendental reason, Coleridge argued that lofty ideas, not matter, should be at the center of any true system of philosophy. Foremost on Coleridge's list of philosophers who were guilty of the converse was Spinoza, whose notion of God as "substance" made him the *bête noire* of generations of spiritual European intellectuals, including George Boole and other mathematical idealists in the nineteenth century.[71] In opposition to Spinoza's brand of philosophy, Coleridge asserted that there were "organs of spirit . . . framed for a correspondent world of spirit," that is, faculties of the mind that connect with the noumenal realm.[72] Similarly, he sought to debunk mechanistic materialism, the theory that the world is nothing but matter in motion. In his *Aids to Reflection* (1825), Coleridge identified this threatening philosophy that had arisen out of the Scientific Revolution: "It is exclusively to sensible Objects, to Bodies, to modifications of Matter, that [the materialist] habitually attaches the attributes of reality, of substance. Real and Tangible, Substantial and Material, are Synonymes for him."[73] Coleridge then posed deflating questions for the adherents of this corpuscular philosophy, including the query most crucial for idealists: How does the mind arise out of inert matter?[74] Just as it is ridiculous to expect "the paper, ink, and differently combined straight and curved lines of an Edition of Homer to bear what we understand by the words, Iliad and Odyssey," so is it equally absurd to look to atoms bumping into one another to explain consciousness or life.[75] As Coleridge had declared in an earlier work, matter "could only engender something homogeneous with itself. Motion could only propagate motion. Matter has no *In-*

ward."[76] He bristled at how materialists could not even begin to explain the true wonders of the universe: "And how came the *percipient* here? And what is become of the wonder-promising Matter, that was to perform all these marvels by force of mere figure, weight, and motion?"[77] Clearly something higher was at work in the cosmos—we need only look into our own minds to comprehend that essential truth.

Not content simply to criticize the materialist *Weltanschauung,* Coleridge offered a new vision of science informed by idealism.[78] He did so by emphasizing the supreme significance of timeless laws instead of day-to-day observations: "In whatever science the relation of the parts to each other and to the whole is predetermined by a truth originating in the *mind,* there we affirm the presence of a law."[79] For Coleridge, such laws were not mere generalizations of patterns found in the universe, but rather transcendental ideas that determined those patterns. In his "Essays on Method" in *The Friend,* he highlighted this characterization of scientific discoveries: "Let it not be forgotten . . . if they do not excite some master IDEA; if they do not lead to some LAW . . . the discoveries may remain for ages limited in their uses, insecure and unproductive."[80] Physical data ultimately must lead to the unveiling of some higher, abstract concept, achieving congruence with what Coleridge considered the divine Mind.[81] As Trevor Levere has summarized Coleridge's vision of science, "[He] was passionately convinced that the world was not made up of disconnected fragments . . . Nature's laws, originating in the mind, were god given, and part of the unity of nature."[82] For Coleridge, idealism therefore offered salvation from troubling modern philosophies by illuminating a universe in which both human consciousness and the external world provided evidence of transcendental divinity.

Since scientists expressed their highest laws in the language of mathematics, Coleridge in turn placed that discipline on a lofty pedestal. Unfortunately, he did not possess a great deal of mathematical knowledge. A telling lament from one of Coleridge's notebooks shows how tormented he was about his failure to immerse himself successfully in this critical discipline, even though his teachers included luminaries such as the astronomer and navigator William Wales:

> O! with what bitter regret, and in the conscience of such glorious opportunities, both at School under the famous Mathematician, Wales, the companion of Cook in his circumnavigation, and at Jesus College, Cambridge, under an excellent Mathematical Tutor, Newton all *ne-*

> *glected,* with still greater *remorse!* O be assured, my dear Sons! that Pythagoras, Plato, Speusippus, had abundant reason for excluding from all philosophy and theology not merely practical those who were ignorant of Mathematics.[83]

Pure mathematics was a necessary precursor to all higher regions of thought, Coleridge believed—a sore oversight on his part, indeed. Nevertheless, he studied Proclus, including Thomas Taylor's translation of *The Philosophical and Mathematical Commentaries on the First Book of Euclid,*[84] and such reading made him appreciate the power of the symbols of pure mathematics. Later, Coleridge would proclaim in *Biographia Literaria* that "an idea, in the *highest* sense of that word, cannot be conveyed but by a symbol."[85] Moreover, symbols that point to the Eternal reside deep within our minds: "In looking at objects of Nature while I am thinking . . . I seem rather to be seeking . . . a symbolic language for something within me that already and forever exists, than observing anything new."[86] Victorian mathematicians who envisioned themselves summoning grand, ideal laws through their algebraic systems, rather than creating these laws from scratch, understood well what Coleridge meant.

Furthermore, Coleridge shared with the founders of mathematical logic a hatred of nebulous language. In his *Aids to Reflection,* an aside about semiotic imprecision demonstrated this concern: "I have neglected no occasion of enforcing the maxim, that to expose a sophism and to detect the equivocal or double meaning of a word is, in the great majority of cases, one and the same thing."[87] Like the mathematical logicians who followed him, Coleridge ultimately believed that "all true science is contained in the Lore of Symbols & Correspondences," in a realm where the confusion of everyday language simply does not exist.[88] Although individuals and groups exploit the many meanings of words to promote their viewpoints, in this higher realm only propositions "wholly independent of the will" endure. This neutrality is crucial—a properly formed science should help to establish true religion, rather than antagonize it. When science "remains neutral," when it does not try to dispel faith or offer its own disenchanted "religion," Coleridge concluded, it "becomes an effective ally [of faith] by exposing the false shew of demonstration."[89] George Boole, among others, would use the "unbiased" symbols of mathematics in precisely this way.

In his widely overlooked work *Logic* (probably finished in the 1820s), Coleridge crystallized his ideas regarding the nature and prominence of mathematics.[90] A full three chapters of the manuscript, and a significant portion of the remainder, concerns mathematics, an important focus since Coleridge understood that his case for idealism turned on a single issue: convincing his audience of the existence of objects that are immaterial yet certain. Like Kant (whose work he often creatively plagiarized), Coleridge addressed the skepticism of modern philosophers such as David Hume by appealing to knowledge that seemed to be innate to the mind, existing independently of the external world.[91] Hume believed that mathematics was analytical—that is, based on our observations of the world. For example, we know that 2 + 3 = 5 because we have previously put together 2 apples and 3 apples and gotten 5 apples. In *Logic,* Coleridge strenuously objected to Hume's characterization of mathematics, and he countered with a penetrating question: how can we know the sum of two immense numbers, for example, 35,942,768,412 and 57,843,647, given that we could never count that many apples even with an inexhaustible orchard and decades of free time? Instead, mathematics must consist of pure laws manipulated in the *mind's* eye. In other words, mathematics is synthetic a priori knowledge.[92] "We need only ask ourselves whether . . . we could ever have arrived at the properties of the cycloid or the proportion of the area of the curve to the area of the generating circle" using mere observation, to understand the purely ideal nature of mathematics, Coleridge concluded.[93]

From piercing points such as these, mathematics widened into a philosophical wedge. If we can show that such a priori knowledge exists, Coleridge insisted, we should not be hesitant to accept that additional a priori knowledge is possible, including supreme notions such as the existence of God and the perpetuation of the soul beyond death. Following his three chapters on mathematics, Coleridge thus proceeded to show that other a priori knowledge is indeed attainable—even knowledge of the transcendental realm. Because so much of his argument relied on the case of mathematics, Coleridge's view of the discipline was commensurately grand. For instance, at one point in *Logic* he preached about mathematics, "We have only to attempt raising our minds to a comprehension of the mighty pile and fabric of truth, which (faith in God and the moral law alone excepted) is the proudest honour and glory of the human intellect, that in which above all others it finds the clearest sense of its own permanency and at the same time the most infallible evidence of its progressiveness."[94] For Coleridge, therefore, pure mathematics would serve as a bridge between the material and divine realms, between skepticism and faith. Perhaps the most telling passage in *Logic* comes not from Coleridge himself but from the eighteenth-century poet Mark Akenside, whose revelatory stanzas about mathematics Coleridge quoted at length:

> Such is the rise of forms
> Sequestered far from sense and every spot
> Peculiar in the realms of space and time;
> Such is the throne which man for truth amid
> The paths of mutability hath built,
> Secure, unshaken still; and whence he views
> In matter's mouldering structures, the pure forms
> Of triangle or circle, cube or cone,
> Impassive all; whose attributes nor force
> Nor fate can alter. There he first conceives
> True being, and the intellectual world
> The same this hour and ever. Thence he deems
> Of his own lot; above the painted shapes
> That fleeting move o'er this terrestrial scene
> Looks up; beyond the adamantine gates
> Of death expatiates; as his birthright claims
> Inheritance of all the works of God;
> Prepares for endless time his plan of life,
> And counts the universe itself his home.[95]

Human beings first comprehend the wondrous connection between the human mind and the divine Mind when they encounter the pure forms of mathematics, and are then set on the path to understanding the existence of heaven and the nature of God. Seeing mathematical symbols as transcendental thus placed Coleridge among the most important supporters of pure mathematics in the early Victorian era.

Another central figure of British Romanticism, William Wordsworth (1770–1850), also maintained exceedingly favorable views of mathematics. Although like Coleridge he knew relatively little about the discipline, Wordsworth nonetheless advocated a sublime conception of it. Autobiographically describing his flirtation with "the geometric science," Wordsworth exalted,

> With Indian awe and wonder, ignorance
> Which even was cherish'd, did I meditate

Upon the alliance of those simple, pure
Proportions and relations with the frame
And laws of Nature, how they would become
Herein a leader to the human mind.[96]

The purity and force of mathematics clearly entranced the young poet, and it played a critical role in his intellectual growth. Mathematics, Wordsworth claimed, helped to lift him out of this profane world into the divine realm:

From this source more frequently I drew
A pleasure calm and deeper, a still sense
Of permanent and universal sway
And paramount endowment in the mind,
An image not unworthy of the one
Surpassing Life, which out of space and time,
Nor touched by welterings of passion, is
And hath the name of God.[97]

Wordsworth, echoing Akenside's declaration about the role of mathematics, obviously inherited the Platonic understanding of the discipline as a spiritual endeavor that elevated the human mind. Although a poet, in his own way Wordsworth chased the same eternal laws sought by idealist mathematicians and scientists in the Victorian age. In his poem *Excursion,* for instance, Wordsworth pursued an ideal entity

That is the visible quality and shape
And image of right reason; that matures
Her processes by steadfast laws; gives birth
To no impatient or fallacious hopes,
No heat of passion or excessive zeal,
No vain conceits; provokes to no quick turns
Of self-applauding intellect; but trains
To meekness and exalts by humble faith;
Holds up before the mind, intoxicate
With present objects and the busy dance
Of things that pass away, a temperate show
Of objects that endure.[98]

In his search for such transcendental objects, Wordsworth furthered the tradition of British Neoplatonism, and in turn contributed to the mind-set of many nineteenth-century idealists.

Idealist notions from seminal Romantic figures such as Wordsworth and Coleridge affected a range of intellectuals beyond the creative arts. Mathematicians like George Boole and Benjamin Peirce also felt the immense draw of the Eternal realm conjured by these poets. In some cases their influence was quite direct. For example, Coleridge was a good friend of William Rowan Hamilton, and he sent the eminent Irish mathematician his own valued copy of Kant's *Critique of Judgment*.[99] In turn, Hamilton closely followed the development of Coleridge's own philosophy and criticism, going so far as to copy sections of Coleridge's *Aids to Reflection* and *The Friend* into his notebooks.[100] Hamilton was also friendly with Wordsworth, concurring with his opinion that the best science rose above mere observation into a meditative unity with God's mind.[101] As the mathematician had written when he was twenty years old and in the midst of formulating his mature philosophy, "I know that Science presents to its votaries some of the sublimest objects of human contemplation; that its results are eternal and immutable verities; that it seems to penetrate the counsels of Creation, and soar above the weakness of humanity."[102] Victorian mathematicians such as Hamilton agreed with Wordsworth and Coleridge in claiming that truth was divine and that it existed in the form of heavenly symbols and laws. Combined with the older Platonist tradition, the religious idealism of the Romantic movement thus generated a school of thought in Britain and America that treasured mathematics as the way to ascend to the realm of spirit.

Descriptions of the 1846 discovery of Neptune highlighted how Romanticism helped Victorian mathematical idealists translate their awe about the planetary unveiling into words. A gleeful passage about the mathematician's work from J. P. Nichol's *The Planet Neptune* furnishes an apt example, simultaneously recalling Wordsworth's odes to the ideal and the Romantic painter Caspar David Friedrich's iconic painting of a solitary figure on a mountain top above the clouds:

> Am I indeed overcharging it, in deeming that the attitude of the Inquirer here approaches the Sublime? Standing on the summit of a pinnacle to which the loftiest minds had heretofore looked with rather an aspiration than a hope, his first glance is even farther on-

> wards,—his thoughts stretch towards remoter Altitudes still lying cloud-capped, but which may one day be scaled, and the perspective beneath them spread before the triumphant eye of Man![103]

For Nichol, as for so many other intellectuals influenced by Romanticism, mathematics clearly transported one to a transcendental place.

Religious Purity and Pure Mathematics

Ancient Platonist, early modern Neoplatonist, and Romantic testaments to the lofty character of mathematics united with a widespread nineteenth-century desire to return to a primeval faith. It is perhaps a truism to say that since the Protestant Reformation most theological reformers have considered themselves to be purifying religious ideas and practice, yet purification is an apt way to describe the synthesis of mathematics and faith in the Victorian age. By turning to symbols they believed came from heaven, religious mathematicians felt they could rise above the insecurity and chaotic diversity of human culture. Faced with an age they saw as corrupt and defective, these intellectuals sought to use pure mathematics to cleanse their muddied world. In an odd way, this devotion to the simplicity and transcendence of pure mathematics was thus kindred with the Gothic revival associated with Britons such as John Ruskin and A. W. Pugin, with elements of the Second Great Awakening in the United States, and with many other spiritual and spiritually tinged movements that proliferated in the nineteenth century in response to the perceived threat of a secular modern world and the uninspired religiosity of the established churches.[104]

To use an older comparison, in Augustine's sense mathematical idealists in the Victorian era saw themselves as a new City of God, a community that spoke a heavenly dialect and was dedicated to the one true faith that spanned the centuries and the barriers of language and culture. George Boole, for example, believed that "the progress of knowledge and the arts . . . forms a bond which connects the different generations of men together by interests and feelings wider than those which are merely national."[105] Indeed, Boole often spoke like Augustine, a model for living devoutly in a profane age. The mathematician referred to "the people of the unseen God" and how "in all ages it had been their duty to keep themselves from too close contact with idolatry."[106] In a series of emotional poems written at the same time as his initial work on mathematical logic, Boole honored this timeless brotherhood of learned believers. He was certainly no Wordsworth or Coleridge, but Boole's poetry shows that he was equally moved by sublime truth. One poem, dedicated to his mentors, began with a search for the "city" of faithful teachers:

Fellowship of spirits bright
Crown'd with laurel, clad with light
From what labours are ye sped,
By what common impulse led,
With what deep remembrance bound,
From the mighty concourse round
Do ye thus together stand,
An inseparable band?[107]

These noble compatriots, Boole believed, were to be found "beyond time and place"—a college that stretched across the ages and the continents. Included in this fellowship were those who fought for justice and ecumenical unity:

All who felt the sacred flame
Arising at oppression's name
All who toil'd for equal laws
All who lov'd the righteous cause
All whose world-embracing span
Bound to them each brother man.[108]

The mathematician did not merely honor religious leaders. Equivalent positions in his heavenly city were reserved for the Copernicuses and Newtons:

All who with a pure intent
Were on Nature's knowledge bent
Watch'd the comet's wheeling flight
Trac'd the subtle web of light
And the wide dominion saw
Of the Universal Law.[109]

Boole considered all pursuers of God's divine truths, whether ethical or scientific, as part of a timeless effort to unify the faithful and advance God's dominion. His declarations thus truly restated the main themes of Augustine's *City of God,* and Boole concluded his poem with two stanzas that could have been written by the Church Father:

If with pure and humble thought
For the Good alone they wrought,
When the earthly life is done
In the heavenly they are one.

And their souls together twine
In a Fellowship divine,
And they see the ages roll
Onward to their destin'd goal,
Dark with shadows of the past
Till the morning come at last
And an Eden bloom again
For the weary sons of men.[110]

Divine truth, Boole proclaimed, united its advocates beyond the ages and petty cultural distinctions. Mathematicians therefore had a chance to become a part of the glorious "Fellowship divine," to work in the service of a higher purpose. In this sense the pure mathematical and logical revolution of the nineteenth century could be a spiritual quest as well as a technical one. Boole and many other Victorian mathematicians labored in the belief that they were spreading the ideas of God to the brotherhood of humanity.

Despite such resonance with centuries-old Christian themes, however, Victorian mathematical idealists diverged significantly from theologians like Augustine. Although most were nominally Christians and believed in the ethical message of Jesus, the idea of communing with a unified divine Mind naturally pushed them toward a denial of the Trinity and a skepticism about the importance of the Church and the clergy. Unsurprisingly, many nineteenth-century pure mathematicians strayed far from orthodoxy, drifting especially toward Unitarianism. Augustus De Morgan was a prominent Unitarian, as was Benjamin Peirce; George Boole, though fearful of declaring his faith publicly, was closest in spirit to Unitarianism and cherished the work of the American Unitarian William Ellery Channing above virtually all other theologians. This trio of leading pure mathematicians thought that the "Fellowship divine" was not to be found in traditional ecclesiastical institutions but in an upstart denomination they found to have a strong idealist and ecumenical bent. Indeed, the mixture of Unitarianism and mathematical idealism was a powerful undercurrent to research in pure mathematics and mathematical logic in the Victorian age. Peirce, born within the broad theological latitude of the United States and unrestrained in his religious proclamations, most clearly exhibits this important bond between nineteenth-century Unitarian theology and pure mathematics, between religious idealism and the "heavenly symbols."