Math for Math's Sake: Non-Euclidean Geometry, Aestheticism, and *Flatland*

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WHEN SAMUEL TAYLOR COLERIDGE SPEAKS 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," it is surprising, wide-ranging though his interests are, to find that he speaks not of poetry or philosophy but of geometry ("On Mathematical . . . Synthesis" 199). Indeed, he not only rhapsodizes over geometry's powers but finds the thought of a challenge to its privileged status as an a priori synthetic faculty "too monstrous to have ever been distinctly believed" (199). For Coleridge, the Euclidean conception of homogeneous space, along with the postulates and axioms that described the relations of points, lines, and figures in it, constituted an unimpeachable body of knowledge and an essential framework for thought itself. Nor was he alone among his contemporaries in regarding geometry as the summum bonum of human knowledge. As the prominent mathematician William Kingdon Clifford explained, since the writing of Euclid's *Element*s,

> Mathematic was no longer the merely ideal science of the Platonic school, but had started on her career of conquest over the whole world of Phenomena. The guide; for the aim of every scientific student of every subject was to bring his knowledge of that subject into a form as perfect as that which geometry had attained. ("Postulates" 552)

The science historian Joan Richards explains the reason for this preeminence: "the indubitability and exactness of geometrical truth were seen to be unique among man's scientific insights. With geometry, humans seemed to have bridged the Cartesian gap between mind and body, to have transcended the confines of subjective being and attained a true understanding of the external world" (2).

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But if geometry was the uncontested queen of the sciences in the first part of the nineteenth century, by mid-century new mathematical theories from the Continent were to challenge her preeminence. And because Euclidean geometry not only served as an epistemological linchpin but also played a foundational role in education (we might think here of Tom Tulliver's tutor in *The Mill on the Floss*, who believes "the classics and geometry constituted that culture of the mind which prepared it for the reception of any subsequent crop" [Eliot 139]), the unsettling effects of the challenge to geometry's preeminence were felt beyond the handful of Cambridge University mathematicians who first responded to it. The new theories, instead of elaborating on Euclidean geometry, rethought its foundations. Such speculations were disruptive not because they disproved Euclid or rendered his work obsolete; it was enough simply to have demonstrated that Euclidean space, so long regarded as the groundwork of knowledge, need not be taken as a given. To have shown this was to have shown that absolute knowledge was not available even in the domain of geometry. As Clifford explained in 1872, taking the new theories seriously meant recognizing that "exact" knowledge must be understood to be "different in kind from any knowledge that we now possess" ("Exactness" 550):

> For what Copernicus was to Ptolemy, that was Lobatchewsky to Euclid. . . . And the reason of the transcendent importance of these two changes is that they are changes in the conception of the Cosmos. . . . And in virtue of these two revolutions the idea of the Universe, the Macrocosm, the All, as subject to human knowledge, and therefore of human interest, has fallen to pieces. ("Postulates" 553–54)

The effects of this Copernican revolution were felt not only in the sciences, broadly construed, but also in the arts. For just as the Euclidean system held out the promise of perfect scientific accuracy, it seemed to guarantee the possibility of representational transparency. The language and claims of geometry were understood to provide an objective account of the world. Moreover, Euclidean geometry had the virtue of being founded on a small set of precise definitions and being demonstrable by means of geometric constructions, physical models of abstract truth. A description of a course to be offered at University College in 1876 underscores the pedagogical value of such representations: "One of the great advantages of the purely geometrical methods is that all operations are performed by constructions, mostly in three dimensions. Thus the student learns to realize figures in space . . ." (Henrici 31). Geometric figures were considered mimetic rather than merely conventional. Indeed, classical geometry set so high a standard for representational reliability that it made even the narrowly defined and rigorously used algebraic symbols of Cartesian or "analytic" geometry (a geometry of algebraic equations derived from the Cartesian coordinate grid) appear arbitrary and unreliable by comparison. Augustus De Morgan, mathematician and educator, remarked that classical geometry was an invaluable "aid of algebra to assist in gaining representations of functions" ("On the Signs" 243) and feared that without this grounding algebra might prove to be nothing more than "symbols bewitched, and running about the world in search of meaning" (Rev. 311). Similarly, George Salmon pointed out that while in analytic geometry one could generate equations that seemed to render distinct spatial figures equivalent, Euclidean spatial representations were reliably unambiguous and could in fact be used to diagnose such misleading equivalences:

> We know what a circle is before we know anything about the equation $x^2 + y^2 = a^2$, and any interpretation of this equation differing from . . . our previous geometrical conception, must be rejected. . . . [I]f these curves differ from a circle in form and properties, then it is an *abuse of language* to speak of them as branches

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> of the circle. . . . It is, in short, no better than a *mathematical pun*. (302; my emphasis)

Salmon takes for granted that we know what a circle is, as it were, intuitively; it is self-evidently amenable to what he calls a "real interpretation" (302). Algebra, on the other hand, is a nonmimetic symbolic system, one that must constantly be tested against the transparency of classical geometry. The revelation that Euclidean geometry might itself be merely conventional, one symbolic system among others, meant that not only the belief in "exact" knowledge but even the dream of transparent representation had "fallen to pieces."

Victorian mathematicians were, then, deeply invested in theories of representation. Literary critics and art historians have noted, and in some cases studied at length, the influence of late-Victorian mathematical developments on modernist conceptions of space. But as I will show, the development of non-Euclidean geometry had an earlier and more fundamental influence on developments in aesthetics because Euclidean geometry had been understood to be centrally concerned with representation and the mediation of ideal and real. To relinquish faith in the representational powers of classical geometry was to recognize that symbolic systems generally, while they might be characterized by internal coherence, might not be amenable to a "real interpretation."

Edwin Abbott's *Flatland* (1884), a novel about a society of planar shapes who live and die by the laws of geometry, speaks directly to this crisis. The novel has two parts: in the first part, a first-person narrator, who is literally a square, describes the two-dimensional society of geometric shapes in which he lives. In the second part, the narrative proper begins, as A Square tells us of his trip to Spaceland and his subsequent failure, on his return home, to convince his fellows of the existence of a third dimension. The book, then, aims to teach us by example the value of being open to the possibility that there may be more dimensions than we are accustomed to imagining. Although *Flatland* is an outlier in the realist tradition, the novel self-consciously comments on it, allegorizing the danger of too ready a belief in the viability of "realistic" representation. Indeed, I would argue that the features that make *Flatland* hard to assimilate to the canonical novel tradition, its flouting of the protocols of realist characterization and plotting, are the same features that make it uniquely useful to the critic seeking to understand late-nineteenth-century theories of representation.

Much modern criticism of the novel has understood Abbott's anxiety regarding the limits of knowledge in terms of the Victorian crisis in religious belief.[1] I will argue, however, that in *Flatland* Abbott locates in geometry not only the origin of but also the solution to the problem of uncertain knowledge. For modern geometry was, as we shall see, concerned with aesthetics, and, in terms that bring to mind the formalist investments of the avant-garde painting of his day, Abbott suggests that aesthetic pleasure, particularly the perception of form and color, is sufficiently valuable to compensate for the failure of signs to provide absolute truth. In this book, his one novel, Abbott the pious schoolmaster closes ranks with such unlikely contemporaries as James McNeill Whistler and Walter Pater. Recognizing Abbott's commitment to the strictly formal properties of signs helps us not only to understand better the place of this eccentric book in its culture but also to see just how far-reaching and unpredictable the effects of developments in mathematics were.

[I]

In book 6 of the 1805 *Prelude*, William Wordsworth describes the consolations of Euclidean geometry for thinkers of the early nineteenth century who were concerned with the status and nature of representation:

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> With Indian awe and wonder . . .
> . . . did I meditate
> Upon the alliance of those simple, pure
> Proportions and relations, with the frame
> And laws of Nature—. (142–47)

This rehearsal of the notion that geometry allies the ideal with the real is followed by an even grander claim, that geometry is a conduit for "deeper," ultimately divine truths:

> 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. (154–57)

Famously, Coleridge—drawing on German philosophy—gave this link to divine truth through human representations a name: symbolism. The Coleridgean symbol, like the Bible, is simultaneously literal and metaphoric; it "is characterized by a translucence of the special in the individual or of the general in the especial or of the universal in the general. It always partakes of the reality which it renders intelligible; and while it enunciates the whole, abides itself as a living part in that unity of which it is the representative" (*Lay Sermons* 30). That is, the symbol has the virtue Coleridge's contemporaries assigned to geometric representation: it seamlessly yokes ideal and real. If the presumption of a divine order underwrote the viability of symbolic representation, the faith in Euclidean geometry provided its secular, scientific counterpart. As the Victorian mathematician James Sylvester remarked, many of his contemporaries ranked Euclid's *Elements* as "second in sacredness to the Bible alone" (262).

That the nature and even the existence of the divine moral order became subject to tremendous uncertainty over the course of the nineteenth century is one of the truisms of Victorian studies. In Matthew Arnold's famous formulation, the "Sea of Faith" was, in his age, retreating with a "withdrawing roar" (lines 21, 25). Most historians attribute this retreat to the advent of Darwinian evolutionary theory, although concerns regarding the legibility of God's creation and the reliability of representation extended well beyond the domain of natural history. Catherine Gallagher links the self-consciousness of the great realist novels to the "liberal break with descriptive [proportional] representation" in the more conservative political climate of the 1860s (233). Similarly, Isobel Armstrong argues that, given Thomas Carlyle's "old analogy between language and money as forms of substitution," the financial crisis of 1866 contributed to making "*[l]anguage* [itself] the site of renewed ideological conflict" (385, 384). As its own transparency came to be questioned, geometry could no longer shore up an already fading faith in other representational systems. In *Metaphysics; or, The Philosophy of Consciousness* (1860), H. L. Mansel turns to geometry to show that it fails to ground language, which is like algebra and thus has no essential significance:

> *A round square* or *a bilinear figure*, is, as a form of speech, quite as possible as *a straight line* or *an equilateral triangle*. . . . Language, like algebra, furnishes a system of signs, which we are able to employ in various relations without at the moment being conscious of the original signification being assigned to each. . . . Like the bank-note, it is the representative of value without having an intrinsic value of its own. . . . (188–90)

The challenge to Euclidean geometry, which was to change its status forever, came in two forms and had its origin in the long-perceived difficulties with Euclid's final, or parallel, postulate.[2] The parallel postulate did not seem as obvious or intuitive as the others and prompted numerous efforts by later mathematicians to reconceive it as a provable theorem, but to no avail. In the early nineteenth century, several mathematicians, working largely independently, gave up on the project of proving the postulate and decided instead

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to rethink the foundations of geometry without it—to imagine versions of space in which parallel lines do in fact meet. The "synthetic" non-Euclidean geometers Nikolay Ivanovich Lobachevsky and Farkas Bolyai created geometric systems that did not take the parallel postulate as a given but discovered they were nevertheless able to develop coherent accounts of space; the fact that they could make their models internally consistent challenged the uniqueness and inevitability of Euclidean space. At the same time, the "metric" geometers Georg Friedrich Bernhard Riemann and Hermann von Helmholtz analyzed the component parts of the classical notion of space, focusing on assumptions where alternative conceptions were possible. As Clifford notes, "[T]his very disentangling and separation of [the assumptions of geometry] is sufficient to deprive them for the geometer of their exactness and necessity" ("Postulates" 565).

Homoloidal Euclidean space—continuous, flat, and consistent, such that bodies can be moved about without altering their shape or size—was so foundational not only to mathematical study but to accounts of knowledge as such that these new theories met with considerable resistance. Even a mathematician as highly regarded as Carl Friedrich Gauss never published his researches in this vein. The challenge to Euclid was nevertheless recognized as a powerful one, one that had implications for the way representation was understood to work. In 1882, Samuel Roberts, the president of the London Mathematical Society, gave an address entitled "Remarks on Mathematical Terminology, and the Philosophic Bearing of Recent Mathematical Speculations concerning the Realities of Space." Roberts criticizes the new geometry precisely on representational grounds; in essence, he accuses Riemann of performing a linguistic sleight of hand: "The multiply extended magnitudes of which he speaks are quantitative conceptions, after all. In certain cases, we can fit them to real cognitions. They are not, in that case, the cognitions, but an expression of certain quantitative relations to which the cognitions conform" (12). For Roberts, the counterintuitive claims of non-Euclidean geometry are fictions that fail not only as empirical descriptions of the world but even as ideas.

The definition and value of what Roberts calls "real cognitions" were at the heart of debates over non-Euclidean geometry. Hermann von Helmholtz, whose writings on non-Euclidean geometry were influential in England because they spoke directly to the epistemological implications of the new mathematical investigations, understood how essential notions of conception and representation were to the new geometries. Helmholtz published a series of articles on non-Euclidean geometry in the journal *Mind*, articles that have been recognized as precursor texts to *Flatland* because in them Helmholtz imagines beings who live in alternative spatial worlds: "Let us, as we logically may, suppose reasoning beings of only two dimensions to live and move on the surface of some solid body. . . . If such beings worked out a geometry, they would of course assign only two dimensions to their space" ("Origin" 303). After developing this scenario at some length, Helmholtz goes on to imagine beings living on the surface of a sphere or the surface of an egg and even to speak of the men who live on the other side of a convex mirror. Such imaginings are not mere flights of fancy intended to demonstrate unfamiliar models of space in anecdotal fashion. They have, instead, the status of proofs, for Helmholtz's claim is that if such spaces can be conceived and represented to others, they are mathematically significant, however difficult their conception and representation might be. Helmholtz hints at his ultimate target—Kantian epistemology—when he asks at the beginning of the article whether Euclidean propositions are "inherited from the divine source of our reason as the idealistic philosophers think" (302). In a follow-up to this article, Helmholtz goes on to

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show that since non-Euclidean spatial worlds can be imagined, Euclidean space cannot be presumed to be an a priori intuition ("Origin [II]" 212). Helmholtz is less interested in establishing the validity of particular geometric axioms than he is in understanding the nature and limits of the conceivable and representable: "By the much abused expression 'to represent' or 'to be able to think how something happens' I understand—and I do not see how anything else can be understood by it without loss of all meaning—the power of imagining the whole series of sensible impressions that would be had in such a case" ("Origin" 304). The value of a geometric system lies not in its relation to reality but in its formal coherence, its capacity to generate a "whole series" of internally consistent impressions.

Helmholtz was not the only mathematician to use fictional scenarios to describe alternative experiences of space; such scenarios appeared in numerous journals during the 1880s and 1890s. As early as his 1873 lecture on the current state of mathematical knowledge, Clifford spoke of the experience of people living entirely on the surface of a sphere ("Postulates" 563). Imagination was understood to be fundamental not just to these fictions but to the mathematics that underlay them. Indeed, one of the first English references to Lobachevsky's work was to an article titled "Imaginary or Impossible Geometry" (Kelland 434), and James Sylvester, president of the British Association for the Advancement of Science (BAAS) in 1869, spoke excitedly of "the doctrine of the imaginary and inconceivable" (261). Abbott's *Flatland* is less an aberration than an elaboration of a fictional genre established within mathematics itself.

Highly imaginative, these mathematical fictions proffer a fundamentally relativistic conception of truth. They show not only that there are other ways of comprehending the world but that these other ways are potentially infinite in number. Once an alternative to the singular status of Euclidean space has been accepted, the proliferation of possible spaces is unending. Unification becomes impossible, and no one system of knowledge can take precedence over any other. We begin to understand how Euclidean geometry could have been regarded "as one of the advanced outposts of the British Constitution" (Sylvester 262). Helmholtz discusses the epistemological implications of this relativism in one of his anecdotes. He begins by describing the image of a man in a convex mirror, a mirror like one of the "common silvered globes set up in gardens," explaining that if he were "measuring with a rule a straight line from the mirror," the image of the man in the mirror "would contract more and more the farther he went, but with his shrunken rule the man in the image would count out exactly the same number of centimetres as the real man" ("Origin" 315, 316). That this anecdote serves to demonstrate the unfamiliar characteristics of curved space is clear enough, but Helmholtz goes on to make a claim that recalls Alice's experiences in the looking-glass world. If the men in the mirror

> could look out upon our world . . . they must declare it to be a picture in a spherical mirror . . . and if two inhabitants of the different worlds could communicate with one another, neither, so far as I can see, would be able to convince the other that he had the true, the other the distorted relations. (316)

Here there is no singular, absolute truth, just a set of relations that looks one way from one vantage and another way from another. In the final chapter of *Through the Looking Glass*, Alice wonders if she dreamed the looking-glass world or if its Red King dreamed her (Carroll 343–44). Helmholtz's readers too could ask, "Which dreamed it?"[3] Once geometry relinquished its claim to bridge the gap between ideal and real, it became an exercise of the imagination, not always immediately applicable to the solution of real-world problems but compelling for its internal coherence; it became "art."

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[II]

If geometry came to look like art, the art of the end of the century came to have much in common with geometry, a modern geometry whose virtues were understood to be formal rather than descriptive. To understand the features of what might be called non-Euclidean aesthetics, we cannot do better than to examine the most fully developed and famous mathematical fiction of the Victorian period: Edwin A. Abbott's *Flatland*. While *Flatland* can be read as a jeu d'esprit, social satire, or math lesson, it is difficult to talk about all these aspects of the book together, and its critics have typically focused on just one of its many unusual features. I would argue that this critical simplification is a response not only to the book's generic hybridity but also to its complicated aims, for the book is centrally concerned with the nature of representation itself. This is felt most obviously, of course, in its bold effort to imagine geometric figures as characters. More important, however, the loss of representational transparency is a major theme of the book. Part 1, "This World," is, in essence, about the failure of even geometric figures to function as symbols in the Coleridgean sense. Although Flatlanders believe that to know each other's shape is to know each other's essence, we as readers are urged to question this faith. This first part of the book dramatizes, in literal terms, the representational opacity of even Euclidean geometry. Part 2, "Other Worlds," moves on to consider the proliferation of conceptions of space post-Euclid, conceptions constrained only by the limits of the imagination and the difficulty of representing and interpreting the unfamiliar. The Linelander who lives in one dimension cannot believe in a two-dimensional world when it is described to him; the Flatlander who lives in two dimensions finds it hard to comprehend three even when a world of three dimensions is shown to him; and, by implication, we who live in three dimensions—"Spacelanders"—find it nearly impossible to imagine the existence of four dimensions.

Critics of *Flatland* have shown how part 1 of the novel is a satire of Victorian misogyny and class bigotry; but, more than this, part 1 is a rumination on the social significance of the belief in representational transparency. The characters of Flatland believe that outward shape corresponds exactly to inner character and therefore to social worth. That belief has disturbing social ramifications, for Flatlanders are dogmatic to the point of violence about the inevitability of their interpretations of shape. Of course, for us as denizens of three dimensions, the scientific and moral certainties of Pointland, Lineland, and Flatland are ironized from the outset. But these beings not only willfully misconstrue the larger world but also misrepresent themselves to themselves. Flatlanders persist in understanding their society in terms of idealized, regular—and therefore perfectly legible—geometric shapes, even though they know that many of their fellows are irregular and that even the elite circles are not perfectly circular. They insist, furthermore, that geometric shape, or angularity, determines moral character and social status. The narrator, A Square, is, by virtue of his configuration, a professional man. The sharper-angled triangles comprise the lower classes and the wider-angled polygons the higher ones (43–44). A Square presents the social relations between the geometric figures of Flatland in terms of what he calls the "Laws of Nature": for him and his kind, shape is definitive (e.g., 44, 47). *Flatland*'s critics have noted the satiric tone generated by this excessive assurance. A Square himself, like the speaker of a Robert Browning monologue, unwittingly gives us sufficient information to lead us to question the accuracy of the Flatland interpretation of shape. Not only are members of the priestly class, the circles, deceitful and self-serving, but they maintain their power by means of violent repression,

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particularly execution. The violent assertion of the transparency of geometric representation registers that this transparency is, in fact, not self-evident. Indeed, A Square's own name reveals the nontransparency of Flatland nomenclature. His name is an exact description of what he is, "a square." But it is at the same time a mathematical pun: "A squared," or "A^2," the algebraic rendering of a square with sides of length "A." On the title page of the 1884 Blackwell edition, the "author"'s name is actually given as "A Square^2" (11). Ambiguity complicates representation even in the Euclidean plane that is Flatland.

Critics have long understood that *Flatland* society satirizes British class consciousness. But, as we have seen, *Flatland* also satirizes the hubris of English (Euclidean) science, a hubris presented here as little more than a compensatory response to the real vagaries of scientific knowledge in the later nineteenth century. For the problem with Flatland culture is not simply that social life is more complicated than an ascending scale of angles will allow. The limitations of geometric knowledge are underscored by the fact that Flatlanders not only find it hard to know what signs signify but have difficulty even perceiving signs accurately. This perceptual problem arises out of the physical organization of Flatland itself: from within two dimensions, all shapes appear to be nothing but points or lines. Thus, A Square describes Flatlanders as "very much like shadows" (33) and speaks passionately about the way the visual limitations of Flatland life make the most basic knowledge of one's environment difficult to obtain. Although A Square laments the difficulty of distinguishing friends, Flatlanders toil under a more basic disadvantage: in their world of shadowy lines, they are constantly in danger of impaling themselves on sharp points they cannot even see. In this way, Abbott not only dramatizes the perceptual prejudices of his contemporaries by forcing them to confront the different experiences of the inhabitants of Flatland, Lineland, and Pointland but also figures the condition of nineteenth-century English knowledge in his account of Flatlanders' struggle simply to see the shapes around them.

In his religious writings, Abbott's solution to the problem of uncertainty is faith. He argues that belief is essential to all knowledge, including scientific knowledge: "A perfect circle you never saw and never will see: yet it is as real as a beefsteak and a pint of porter. I believe in a perfect circle by Faith" (*Kernel* 32). However, Abbott's confidence in the capacity of symbols to bridge ideal and real worlds is not always so robust: "As Solidland may be called more 'real' than Flatland, so Thoughtland may be found more real than Factland. We really *know* nothing whatever about what is 'real.' We have only faith and feeling about it" (*Apologia* 11–12). In *The Kernel and the Husk*, Abbott defines absolute knowledge as "an identity between our mental affirmations and those of the Creator" and, in a line reminiscent of Clifford, remarks that it is "possessed by no man." On the other hand, "[k]nowledge (relative and ordinary) is (very often) a name loosely given to a harmony between our mental affirmations and the affirmations of the vast majority of those who have (or are thought by the majority to have) the best opportunities for observation and judgment" (374). Human knowledge is always an approximation to truth, just as representation functions by approximation—hence the series of parenthetical qualifications in Abbott's definition. In *Flatland*, his one novel, Abbott does not offer a religious response to the shifting grounds of knowledge and the eccentricities of representation. Insofar as religion does appear in this novel, it takes the form of an overblown evangelizing zeal. Instead, the novel draws on the mathematical turn to the imagination to find consolations of another kind: aesthetic. Indeed, it finds an answer to the vagaries of scientific knowledge in the body of theory that had rendered scientific certainty obsolete: non-Euclidean geometry.

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Abbott's turn to the insights of non-Euclidean geometry is most obvious in the fact that the novel encourages readers to imagine the features of four-dimensional space. But for Abbott, the most important lessons of non-Euclidean geometry have to do not with space per se but with representation. Despite *Flatland*'s pedagogical character, the book seems less concerned with the content of non-Euclidean theory than with its aesthetic implications. This is particularly apparent in the novel's focus on the vagaries of appearances in its account of space. In this, Abbott shows an affinity with late-nineteenth-century geometers, especially practitioners of the most popular version of non-Euclidean geometry in England, projective geometry. Although it included some unsettling non-Euclidean features, projective geometry allowed the fairly conservative English mathematical establishment to hold some of the more troubling aspects of the argument over Euclidean geometry in abeyance. Commonly referred to by contemporaries simply as "modern geometry," projective geometry focused on the laws that govern the projection of three-dimensional figures onto a plane. It had its roots in painting, where the rendering of three-dimensional figures on a two-dimensional screen was, from the Renaissance onward, a central preoccupation and led to the development of various systems of geometric perspective. The nineteenth-century revival of projective geometry was stimulated in part by a desire to rediscover immediate, visual truth, a truth unencumbered by the arbitrariness of representation.

Nevertheless, the premises and theorems of projective geometry had some notably arcane features. In particular, the projective geometer's non-Euclidean "points at infinity" and "imaginary points" seemed to many to be disturbingly ungrounded. More important, just as the laws of perspective, despite their rational character, describe the subjective visual distortion of three-dimensional space, projective geometry is ultimately more concerned with appearances than essences, with the way a single figure or shape can take a variety of forms if made to undergo projection and section. Thus, a circle, projected onto a screen at an oblique angle, will take the form of an ellipse. Using the visual simplification of three-dimensional objects as a cue, projective geometers focused on the common properties of shapes typically regarded as essentially different. In projective geometry, the specificities of magnitude and even shape are subordinated to the laws of formal perception. In an elementary treatment of the subject from 1852, John Mulcahy describes the procedure: "Let a figure be conceived to undergo a certain *continuous* variation, and let some *general* property concerning it be granted as true, so long as the variation is confined *within* certain limits" (96). The resonance with Darwinian theory, with its challenge to static categories, is clear. Forms here are too fluid to correspond to fixed essences. The projective geometer cannot, as Salmon did, speak of knowing "what a circle is" as if it were a given. Disregarding length, distance, and size—the stuff of quantitative mathematics—and focusing on the transformation of shape, projective geometry derives its power from its interest in formal variation. Although still devoted to a notion of foundational truth, projective geometry reveals in its practice a preoccupation with form that anticipates the twentieth-century conception of mathematics as a formal rather than a descriptive science.

Form is, similarly, the paramount concern of Flatlanders, who willingly undergo life-threatening surgeries to change their shape because they take the notion of transformation literally. Since form is all that really matters in Flatland, to change shape is not only to look different but, for all intents and purposes, to be different. And although the book urges us as readers to question the meanings Flatlanders attach to form, it is also invested in and fascinated by form, as its unusual setting—a

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two-dimensional society inhabited not by amoeba-like creatures but by a variety of more or less regular geometric shapes—suggests. Indeed, it is striking that the narrative does not do much to challenge Flatland assumptions about the significance of shape by contrasting the formal configuration of its characters with their "real" essences, a technique that would have been familiar enough from the workings of the realist novel. There are indications that such a contrast could be drawn, particularly with regard to Pantocyclus, a patently vicious member of the circular priestly class, but the book is only minimally forthcoming about the features that would individualize its characters, whom we know largely in terms of their shapes. These characters are both literally and metaphorically flat; it is not simply that their forms fail to signify their essences but that they hardly seem to have an essential character in the first place. The book takes Flatlanders to task for their interpretations of form, but it does not challenge their obsession with form per se; after all, their safety depends on their capacity to recognize the forms around them to avoid colliding with them. *Flatland* is at once suspicious of our capacity to know what signs mean and fascinated by signs and appearances themselves.

That the book consistently gives priority to the workings of formal perception over the content of that perception is most apparent in its illustrations. Like the explanatory diagrams of a geometry textbook, these illustrations are not mere supplements but serve an important pedagogical function: they help readers visualize the spatial relations described in the text. But like the diagrams used in projective geometry, Abbott's illustrations of variant perspectives deal first and foremost in appearances. Whereas the aim of projective geometry is to render three-dimensional objects two-dimensionally, A Square, because he must explain Flatland vision, demonstrates the one-dimensional projection of two-dimensional objects. As in traditional perspective, the vantage of a single eye is presumed, but here the projected image of the shapes the eye encounters is rendered as if on the screen of a single line (fig. 1). As pedagogically useful as these diagrams are for us "Spaceland" readers, one is struck by the fact that they invariably represent Flatland vision only as seen from without; they afford a three-dimensional vantage on two-dimensional vision. That is, while the subject of the book and particularly of these diagrams is the possibility of points of view other than our own, the book does not urge us to identify, even temporarily, with those points of view. This is also true at the level of characterization: the only character whose personality we come to know at all is A Square, and that only obliquely through his conventional, unselfconscious, and largely repellent account of Flatland culture. The novel's diagrams, which would seem to offer an opportunity to provide immediate access to Flatland truths, instead dramatize our distance from them. What matters is not *what* Flatlanders see but the form their seeing takes.

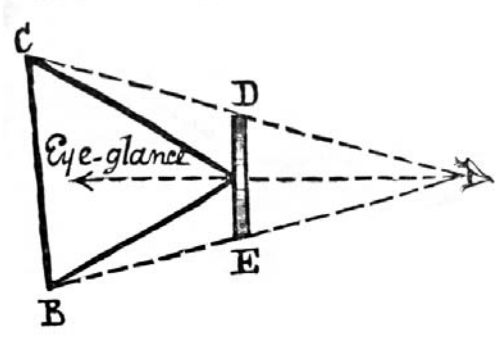


FIG. 1
From Abbott's *Flatland* (67).

While Flatlanders find it hard to judge the angles they perceive no matter how long they study "sight recognition" at university, we Spacelanders flatter ourselves that we do not simply see things from a different vantage but somehow know more or better than Flatlanders do. But Abbott goes to some pains to demonstrate that the point of view of higher-dimensional beings, while formally distinctive, is not in fact linked to greater knowledge. Ab-

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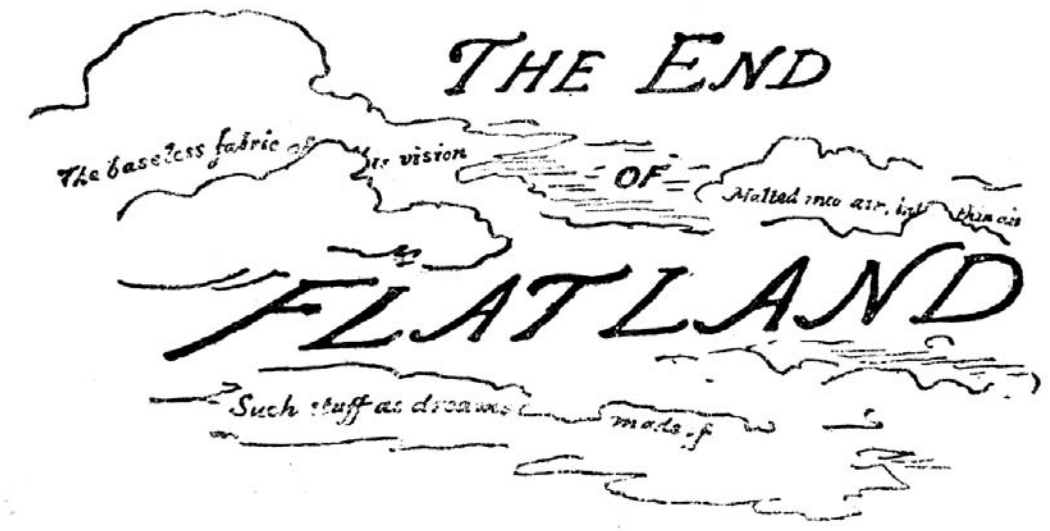
bott drives this lesson home in his account of A Square's experience of Spaceland. A Square discovers in his mentor the Sphere "visibly incorporate, all that I had before inferred, conjectured, dreamed, of perfect Circular beauty" (155). Moreover, from the vantage of the third dimension, A Square sees what he would previously have considered the "insides" of his fellow beings, and he sees them as if from the position of God, up above: "I looked below, and saw with my physical eye all that domestic individuality which I had hitherto merely inferred with the understanding. And how poor and shadowy was the inferred conjecture in comparison with the reality which I now beheld!" (156–57). A Square seems now to enjoy exactly the kind of knowledge associated with Euclidean geometry: a knowledge at once ideal—"perfect"—and corporeal. Instead of shadows, A Square enjoys the clear vision of a distant, all-seeing God: "Behold, I am become as a God. For the wise men in our country say that to see all things, or as they express it, *omnividence*, is the attribute of God alone" (158). But this dream of a divinely sanctioned geometry is misguided, as A Square's inflated language suggests: "There was something of scorn in the voice of my Teacher as he made answer: 'Is it so indeed? Then the very pickpockets and cut-throats of my country are to be worshipped by your wise men as being Gods'" (158). Abbott makes clear that an encompassing perspective and distance are valuable because they remind us that other perspectives exist, not because they give us access to higher truths—hence the drawings not of what A Square sees but of A Square in the act of looking. We are intended not to sympathize with the content of his vision but simply to recognize that it takes a form comparable to, but unlike, our own. What matters is form itself—not Platonic forms, forms as opposed to shadows, but aesthetic forms, forms as opposed to content. Projective geometry's origin in painting takes on a new significance as we recognize that the projection of Flatland figures gives us access not to unchanging divine truths but to temporal aesthetic ones.

Abbott underscores this point by making part 2 of *Flatland* into a farcical conversion narrative. Despite his teacher's warning, A Square insists on understanding multidimensionality in religious terms and uses an elevated, evangelical language to describe it. A Square says that after his visit to Spaceland he woke again in Flatland "rejoicing, and began to reflect on the glorious career before me. I would go forth, methought, at once, and evangelize the whole of Flatland" (187). A Square can only understand his hostile reception and ultimate imprisonment as a fall from grace, and even modern readers have often found it difficult to make sense of the novel's dark ending, its apparent failure to offer A Square poetic justice. After all, we know that A Square is right: there is a world of three dimensions. But Abbott is as ruthless in his satire here as elsewhere: A Square is right about the existence of three dimensions, but he is wrong to assume that the knowledge of three dimensions has any spiritual relevance, that it affords a knowledge of the divine order. The Coleridgean dream of knowledge of the divine is one to which all the characters in the book are prone, even the Sphere, but the novel's events remind us that once the possibility has been granted that there might be more dimensions than we are accustomed to perceive, there can be no complacency; for any n-dimensional space, there is always n+1.

Thus, A Square's final lament—that at times even "the substantial realities of Flatland itself, appear no better than the offspring of a diseased imagination, or the baseless fabric of a dream" (197)—does not simply suggest despair and mental instability but actually tells a kind of truth: all the protagonist's knowledge *is* ultimately formal and insubstantial. It is, as the allusion to *The Tempest* suggests, art. But if the artistic character of his dream prompts despair in A Square, such ungrounded, ephemeral visions

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FIG. 2
From *Flatland* (200).



were a source of excitement for some forward-looking Victorian mathematicians, for whom insubstantiality was linked to beauty. William Spottiswoode, in his 1878 presidential address to the BAAS, described non-Euclidean space as beautiful in the manner of a rainbow: manifold space "is not seriously regarded as a reality in the same sense as ordinary space; it is a mode of representation, or a method which, having served its purpose, vanishes from the scene. Like a rainbow, if we try to grasp it, it eludes our very touch . . ." (21). *Flatland*'s final illustration is of clouds on which are written "The End / of / Flatland" and, in smaller letters, "The baseless fabric of my vision / Melted into air, into thin air / Such stuff as dreams are made of" (197; fig. 2). The content of A Square's vision of higher-dimensional space is nothing but cloud, air, dreams. But this cloudiness describes not only A Square's "vision" of Spaceland but the fiction of *Flatland* as a whole, for this same image of clouds adorns the title page of the book, where the letters that spell "Flatland" run through the center of a bank of clouds. That is, A Square's vision of a world of three dimensions is a fiction of the same order as the book itself; it is not "truth" but a source of enjoyment and imaginative stimulation. And thus the title page itself highlights the vagaries of representation: the clouds that surround the word "Flatland" are inscribed with a range of truncated versions of the word "dimension": "Ten Dim.," "Eight D," "Five Dimen," and so on (fig. 3). Beneath these clouds, zero, one, two, and three dimensions are represented schematically as a point, line, square, and cube; further down still is a drawing, from above (from the vantage of Spaceland), of A Square's home with its inhabitants. This single page thus presents a spectrum of representational techniques, from schematic geometric constructions, clear in outline, to the painterly and (literally and figuratively) nebulous clouds. No one of these representational modes is given priority; all of them, including the geometric figures, must finally be understood as merely suggestive. Their juxtaposition, moreover, makes the incompleteness of each mode, its incapacity to reveal certain truth, more obvious. A Square's recurring complaint that Flatlanders see only "shadows" speaks to a common condition, one that we would do well to recognize and acknowledge.

But the novel suggests that the loss of absolute truth is amply recompensed in the beauty of aesthetic form. It is not by chance

FIG. 3
From *Flatland* (1).

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that *Flatland*'s illustrations allude to the tradition of painting and painterly perspective. Representations might not provide an immediate access to truth, but their stimulation of imagination provides a pleasure valuable in itself. Like Prospero's magic, they delight, entertain, and even promote sympathetic understanding. Thus, sad as A Square's fate might be, and pessimistic as the book is about the capacity of representations to body forth divine truth, the tone of *Flatland* remains comic even to the end. Surprising though this might at first seem, given the norms of affective identification in the realist novel, it makes sense given this novel's primary investment in form. For although the content of the narrative, full of war, sedition, betrayal, imprisonment, and execution, is horrific, we are constantly reminded by its inhabitants' shapes—those one-eyed lines, triangles, and circles—to appreciate them as entertaining artifacts without identifying with them; we maintain our aesthetic distance from them. *Flatland* is not only a book about forms but one whose formal hybridity and eccentricity make it impossible to lose sight of its status as a formal experiment.

While the virtues of aesthetic pleasure are merely implicit in *Flatland*'s illustrations, those virtues are the manifest subject of the book's long and otherwise unmotivated digression on color. The one significant event in Flatland history, we learn, is the "Colour Revolt." Despite his pride in Flatland culture, A Square is forced to admit that from "the aesthetic and artistic point of view . . . life with us is dull." This artistic dullness, we learn, is a result of limitations in the domain of painting: "all one's prospect, all one's landscapes, historical pieces, portraits, flowers, still life, are nothing but a single line, with no varieties except degrees of brightness and obscurity" (79). This criticism of monochromatic art, with its emphasis on linear values, reads like a tongue-in-cheek statement in the *disegno*-versus-*colore* debate that had long played a central role in art criticism. In accordance with the classical belief that the geometric figure embodies permanent truths, line and modeling were traditionally considered the more essential properties of an image. In the English philosophical tradition, this idea is familiar in the form of John Locke's categorization of "solidity, extension, figure, or mobility" as primary, "real qualities" (112, 115), while color is a secondary quality (112). The culture of Flatland, with its emphasis on scientific knowledge and essential truth revealed through shape, is devoted to the ideals of *disegno*.

The nineteenth century, however, witnessed the transvaluation of the *disegno-colore* binary. Johann Wolfgang von Goethe and others explored color perception as a fundamentally subjective phenomenon; Helmholtz himself, influenced by Goethe, was the author of an influential book on optics, in which he stressed the subjective nature of color perception. Among Romantic and Pre-Raphaelite painters, this subjective grounding made color more rather than less vital to the success of a painting. Even John Ruskin, whose reading of Locke led him to regard hue as less important than the delineation of spatial relations, was, in the 1840s, moved by his devotion to early Italian art to argue that "the purest and most thoughtful minds are those which love colour the most" (121). With the Romantic champions of *colore*, A Square suggests that the unscientific use of color is essential to art: "Colour, if Tradition speaks the truth, once . . . threw a transient splendour over the lives of our ancestors in the remotest ages. Some private individual . . . is said to have begun by decorating first his house . . . lastly himself" (79–80). A Square considers the ideology of those engaged in the color rebellion to be "immoral, anarchical, and unscientific" (81). But he also believes that because color is painted on and therefore both artificial and superficial, it is the aesthetic element par excellence. Although, during the years of the Colour Revolt, Flatlanders discovered that color

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could be used as a signifier for shape, this practical function was easily abused. For A Square, color is supremely beautiful precisely because it has no necessary link to "Truth": thus, despite his ostensible condemnation of the color rebellion, he describes its early years as a time of "delight," when Flatlanders lived more richly, enjoying the "glorious childhood of art" (82). Since the enjoyment of color is the quintessential aesthetic experience, the discovery of painting in color prompted the development of other arts as well: "The commonest utterances of the commonest citizens in the time of the Colour Revolt seemed to have been suffused with a richer tinge of word or thought; and to that era we are even now indebted for our finest poetry and for whatever rhythm still remains in the more scientific utterance of these modern days" (83). Color, so long regarded as a secondary quality and inessential adjunct, proves for that reason to be a source of pure aesthetic pleasure.

Abbott suggests, furthermore, that the perception of color, like the perception of form, is not only pleasurable but also personally and socially beneficial. Abbott constructs Flatland society so that the discovery of painting has the power to transform it utterly: with each side painted a different color, a Flatlander's shape could be immediately discerned without the subtle visual scrutiny practiced by elites, thereby rendering upper-class pretensions obsolete. The reference to "the commonest citizens" is not incidental: A Square's account of how members of Flatland's lower classes tried to empower themselves by means of a "Universal Colour Bill" clearly alludes to French Revolutionary struggles and arguments for suffrage reform in Victorian England. The association of political change with art rather than science makes perfect sense, of course, given the claims of Romantic aesthetics. Echoing Wordsworth's remark about the French Revolution, "Bliss was it in that dawn to be alive" (11.1.108), even the conservative A Square exclaims of the early years of the Colour Revolt, "To live was then in itself a delight, because living implied seeing" (82). Here, A Square associates seeing not with the claims of empiricist science but with beauty and art, an art linked to the expansion of human sympathies and an optimistic faith in the power of those sympathies to transform society. Indeed, in the years of the Colour Revolt, not only does the development of art seem indirectly to portend the democratic reorganization of society, but beauty has the power directly to disable the institutions of repression and violence. A Square relates the "famous story how an illustrious Circle, overcome by the artistic beauty of the forces under his command, threw aside his marshal's baton and his royal crown, exclaiming that he henceforth exchanged them for the artist's pencil" (82). Although Abbott challenges the Romantic dream of symbolic representation, he embraces the Romantic faith in the moral salubriousness and social progressiveness of great art. But whereas for Wordsworth and other Romantic artists content is central to the healing function of art, for Abbott simple joy in the perception of beauty is enough. This difference is a function of the perceived limitations of representation in post-Euclidean science and art; A Square rhapsodizes over the "splendour" of the aesthetic precisely because its merits must be distinguished from the merits of truth.

Flatland reveals, then, that Victorian scientific ideas did not simply provide new subject matter for art; developments in Victorian geometry prompted a rethinking of how representation worked. Victorian mathematicians were as earnestly concerned with the transparency of symbols as Victorian poets, and in their development of "imaginary" and "impossible" geometries they experimented with style and genre in the manner of Victorian novelists. Thus, not only did many works of late-nineteenth-century art aspire to the condition of science, but, in important ways, late-nineteenth-century science aspired to the

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condition of art. "Modern" geometers, convinced of the value of the imagination and fascinated by the vagaries of representation, suggested that mathematical knowledge, at its best, was like a rainbow; it was a shadowy projection on a flat screen; it was a tale of distorted men regarding us from inside a looking glass, challenging our faith in certain truth.

Ultimately, then, Abbott the mathematician-schoolmaster produced a novel that has much in common with late-nineteenth-century aestheticism. Although pointedly unconcerned with the moral or social effects of art, Abbott's contemporary Whistler developed a strikingly similar theory of what might be called ungrounded aesthetic pleasure, regarding art, as Abbott did, as being first and foremost about "form and color" (87). Recognizing the self-referentiality of contemporary mathematics helps us understand why Whistler spoke of the "science of the artist" even as he belittled the goal of reproducing "Nature" in painting (84, 85). For Whistler, science was directed not toward a knowledge of deep truth but toward a felicity of superficial effect; he described the artist as one who "picks," "chooses," and "group[s] with science" the "elements of color and form" (84). Beauty, sufficient unto itself, need not deal in Coleridgean correspondences, and Whistler proclaimed that the use of a "vocabulary of poetic symbolism" to render a painting meaningful was misguided (88). As if to stymie his viewer's impulse to look for such correspondences, he produced paintings that were deliberately shadowy and apparitional; in the words of the contemporary art critic Théophile Thoré, "The Woman in White will displease lovers of objective painting, and they will say: 'Ah! How droll that is! No one has ever seen such a woman! She has the air of a phantom!'" (qtd. in Fried 542n87). Like the shadowy shapes of Flatland or the clouds that adorn the novel's title page, the figures of Whistler's paintings insist on their lack of substantiality, their lack of depth: the woman in white is beautiful but, as Michael Fried notes of several of Whistler's subjects, "vacant" (222–32), and she stands on a rug that seems to be laid out vertically rather than horizontally, both she and the rug pressed flat against the picture plane. The figures of Whistler's later paintings, like the inhabitants of Flatland, refuse to signify something else; their literal flatness registers their metaphoric flatness. There is no tenor here, only vehicle: Whistler admonished his audience to look "*at* a picture," not "*through* it" (81), much as Abbott would have us remember the forms and materials of his own art, the ink on a page: "Imagine a vast sheet of paper on which . . . figures . . . move freely about, on or in the surface, but without the power of rising above or sinking below it" (33). Ultimately, painter and mathematician agree that art itself is a flatland, a beautiful surface. *Flatland* celebrates the fact that in the late nineteenth century, geometry relinquished its connection with realism in favor of the aesthetic. And thus geometry, the queen of the sciences, ended her "career of conquest over the whole world of phenomena" by abdicating her throne to the most unlikely of ladies-in-waiting: art.

Notes

1. See, for instance, Jann; Smith.

2. Euclid's parallel postulate reads, "[I]f a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles" (1: 202).

3. "Which Dreamed It?" is the title of the final chapter of *Through the Looking Glass*.

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