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Introduction by **A. K. Dewdney**

The publication in England one hundred years ago of Edwin A. Abbott's *Flatland* was greeted by reviews which ranged from "fascinating" to "mortally tedious." On the one hand, Abbott (1838-1926) had described an amusing and curious two-dimensional world inhabited by flat creatures knowing no space higher than their own. On the other hand, Abbott made of the Flatlanders' ignorance a metaphor suggesting that we solid folk are no better off when it comes to higher realities. While many Victorian readers found Abbott's tabletop world fascinating andi of itself, reason enough for a book, others found Abbott's continuing insistence on the metaphor somewhat distracting. His approach appeared too didactic. Besides, what gave his "gospel of three dimensions" such urgency as to dominate the story?

One answer to this question emerges from a simple review of Abbott's life and work, his concern with religion generally and the Church of England in particular. Such concerns explain not only the urgency of Abbott's message but the form and content of his flat world and the flat society inhabiting it. Viewed closely through the lens of Abbott's satire, the Flatlanders invite our amusement with their pettiness and ignorance, Viewed from a higher vantage point, however, the satirical possibilities shrink in face of the challenge of the third dimension. Satire gives way to sobriety and we, like the Flatlanders, cringe before the possibilities of ascent. This ascent is really Abbott's cardinal point, and while we might imagine all sorts of physical or even theological significances for it, there can be little doubt that Abbott understood the ascent in a fairly specific way not revealed in his book.

Besides its length and breadth, Flatland (or perhaps we should say *Flatland*) has two other dimensions. The physical dimension embraces the world of Flatland and all of its inhabitants. The metaphysical dimension embraces the world "above" Flatland both in its implied relationship to the Flatlanders and in the symbolic content of that relationship for us. We will explore these additional dimensions before returning to Abbott's principal theme.

When we read about Flatland and witness a consistent two-dimensional world whose inhabitants live, move and perceive in harmony with two-dimensional laws, our fascination is really the surface manifestation of a deeper question. Once we have grasped the idea that flat things, objects of infinitesimal thickness, may participate in a physics totally within the plane and quite independent of our own, there is a dawning sense of mystery and wonder. How very oddl Could such a place really exist? This question is at once a philosophic and scientific one and it leads immediately to a host of related questions about our own universe. First, why does our universe have three physical dimensions and not two or four? Second, in what way does the three-dimensionality of our universe affect its physical, chemical, and biological processes? Once this box is opened it becomes very hard to close.

Given a degree of scientific credibility for a two-dimensional universe, we are inclined all the more readily to suspend disbelief in Flatland and its inhabitants. Although something tells us that it is ridiculous to suppose that "real" Flatlanders might be shaped like triangles and other geometrical figures, we accept the geometry as if the figures of Euclid had been given a life of their own and freedom to roam an infinite plane. The visual and tactile experiences of the Flatlanders harmonize with their two-dimensional environment in ways which the reader may easily confirm: for example, a Flatlander's entire visual world is contained within a single line subdivided into the objects of his perception.

The physical dimension of *Flatland* is complemented and, to a degree, even superseded by a metaphysical dimension, the one on which Abbott insisted so strongly. The hero of Flatland is a figure of geometric shape named A. Square because he is one. Mr. Square is a young and idealistic flatlander who is visited one evening by a sphere from "Spaceland", the realm of three dimensions. In Flatland, the social hierarchy. of geometrical beings is arranged so that the many-sided figures rule over those with fewer sides. The most powerful beings in Flatland therefore belong to the priestly class whose members have so many sides that they cannot be distinguished from circles. Imagine Square's astonishment when he is visited by a creature of the highest perfection who materializes in the middle of his room, first as a small circle and then as one of steadily increasing size. This is the noble Lord Sphere manifesting himself in Flatland in the only way he knows–as a cross section. What Square thinks is the whole turns out to be merely a part. This and other insights come only later to Square as he undergoes the most dfficult educational experience of his life, supplemented by a trip to spaceland itself by courtesy of Lord Sphere. Abbott's account of the visitation by the sphere produces, reverberations in our cultural memory: we recall how sages and divines from all spiritual traditions–including Christianity–have reported encounters with angelic or "higher" beings which appeared out of nowhere. What can Abbott's image be but an expression of such an encounter with all of its theological implications intact? The geometry of the participants, Mr. Square and Lord Sphere, serves to neutralize the human content of the encounter and so to express the metaphor at a more subliminal level. We are not *forced* to view the contact as a religious experience but merely as the intersection of a sphere with a plane witnessed by a square. But the vibration is there and is reinforced enough times in the course of *Flatland*'s telling to leave no doubt that the metaphysical dimension is Abbott's main interest. He is trying to tell us something about our human failure to grasp higher realities. But does he mean to tell us, in effect, that God inhabits a fourth dimension or does 'he mean only to suggest that spiritual realities are merely *like* a fourth dimension, everywhere accessible but nowhere visible? This and other questions can be given only partial answers' by examining Abbott's other work's, but the answers are interesting and go a long way toward suggesting the metaphysical dimension of Abbott's metaphor.

Edwin A. Abbott was born in 1838 in London, raised in a solid Anglican family, and finished his education at St. john's College in Cambridge, where he was elected a fellow

at the age of twenty-three. After two years as Assistant Master of the King Edward School in Birmingham, he was appointed head-master of the City of London School, a prestigious educational posting. Ten years later he was made Hulsean Lecturer at Cambridge, a position which undoubtedly pleased him as it gave him the opportunity of worldng out the implications of his own brand of rational Christianity.

Abbott, who had taken a divinity degree at Cambridge, was a devout clergyman and staunch supporter of the established church, taking as his special role the defense of the church against all forms of irrationality and superstition. A great admirer of Sir Francis Bacon and the enquiring rational mind which he exemplified, Abbott sought a complete reconciliation and harmony between his scientific convictions and his religious faith. There are hints among his many religious writings that he saw himself in an almost prophetic role as an exemplar of a new faith which had no dependence on "credulity." In the midst of a controversy arising from a book in which he criticizes Cardinal Newman's doctrine, Abbott declares:

> And when a man feels (as I do) that he has at last attained a profound spiritual truth which will, in all probability, be generally accepted by educated Christians who are not Roman Catholics, before the twentieth century is far advanced, he can well afford to be patient of prejudice.

One of the most important events in Abbott's life and, indeed one of the most important in nineteenth- century England, was the Tractarian controversy. The man at its center was an Anglican priest by the name of John Henry Newman. Vicar of St. Mary's, the University Church in Oxford, Newman published a document called Tract 90 in 1841, a plea that the Church of England return to more traditional doc- trines and practices. The tract created tremendous tension and dissension in the Church and, unable to persuade the Church of his views, Newman became a Roman Catholic in 1845, was ordained in Rome a year later and, ultimately, was made a cardinal by Pope Leo XIII. Newman was a man of tremendous magnetism and his conversion was seen as a direct threat to the established Church. Abbott was among those who could not accept Newman's arguments for change and regarded him as a man who had unconsciously duped himself and would dupe others. Specifically, Newman was prone to "credulity", an unscientific acceptance of unprovable and unlikely things. Although we do not find Newman in Flatland we find everywhere Abbott's stress on logical ability and personal experience as the basis of all knowledge, whether secular or religious.

Abbott was a busy and prolific writer of books, attested to by a bibliography which includes twenty religious works, eleven books of instruction, two biographies, and, of course, Flatland. The religious books range from children's stories of the New Testament to treatises on Biblical criticism. The instructional texts deal largely with English grammar, vocabulary, and good writing, The biographies concentrate on two men, the one Abbott most admired and the one he most despised–Bacon and Newman, respectively. In this literary landscape, *Flatland* stands out as a promontory, so to speak, a strange headland with seemingly little relation to' its surroundings. Why should Abbott, this most rational of churchmen and proponent of sober, inquiring faith

suddenly burst forth into imaginative flower with a work having no precedent and no successor among his books? What is Flatland trying to tell us which the other books cannot?

On closer inspection, Flatland seems a more logical part of Abott's literary output, at least when we reexamine the central concern of his life. Two especially important books provide a clue, *Philomythus: An Antidote Against Credulity* and *The Kernel and, the Husk: Letters on Spiritual Christianity.* in these books Abbott tells us what must be taken on faith and what must be explained in Christianity. Again and again he attacks miracles as illusions or false reports and attempts to replace a belief in miracles by a faith in the "supernatural," a second category which to most readers appears hardly distinct from the first. Yet for Abbott the Supernatural means that which is both "obvious" and "obviously above "nature." The universe, he says, either had a beginning or it did not. Either possibility points to a phenomenon ,outside the scope of nature itself.

How can it not have bothered Abbott that he himself was incapable of explaining "supernature"? Could he really be so sure of a distinct boundary between it and the miraculous? He felt that the Supernatural might.from time to time intervene in the natural world which humans inhabit but to do so it could in no way violate natural laws. This was the kernel of Abbott's belief and it needed support. At the same time such support could hardly come from a seemingly self-contained natural world (of any dimension) or from natural laws. Nor could it come from any logical argument based on the world or its laws. *Flatland* may well be Abbott's attempt to make the Supernatural credible (if not exactly explainable in any strict sense) as a kind of higher-dirnensional influence. If a three-dimensional being could visit Mr. Square, so could a Higher Being have created *Flatland* (and, by implication, our own universe) in the first place. In fact, such a Being is explicitly mentioned in *Flatland* when Square holds converse with that ungraspable paragon of three-dimensional perfection, Lord Sphere:

> My Lord, your own wisdom has taught me to aspire to One even more great, more beautiful, and more closely approximate to Perfection than yourself, As you yourself, superior to all Flatland forms, combine many circles in One, so doubtless there is One above you who combines many Spheres in One Supreme Existence, surpassing even the Solids of Spaceland.

Flatland provides precisely the framework in which the Supernatural may comfortably exist in Abbott's mind. It implies a hierarchy of dimensions within .which and upon which the Supernatural works its plan. If this is the case, how literally does Abbott wish us to take the metaphysical dimension of Flatland? The answer, in a nutshell, is simply "as literally as is necessary to combat credulity. " Abbott would replace credulity with credibility.

Abbott is promoting a view of reality in which the natural and supernatural worlds exist together in the harmony of a multidimensional framework. All would seem logical, Abbott is telling us, if only we could *see.* Then tales of bleeding statues, miraculous cures, and other unlikely things would be understood for what they are the

chimeras and fantasies of unstable and credulous minds. Unfortunately, Abbott's multidimensional metaphysics allows for the very phe- nomena which he so despises: when a statue of the Virgin Mary cnes, why could not her tears be intro- duced from a fourth dimension?

Apart from its physical and metaphysical dimensions, *Flatland* is a fascinating window on English Victorian culture. The most prominent features of Flatland society are its hierarchical structure and the role of women. In both cases geometry is the vehicle of Abbott's satire.

The class structure of Flatland is based almost entirely on how many sides one has. Triangles yearn to become squares while squares look up to pentagons and so on up to the "chief circle" who, in reality, is a polygon with several hundred sides. It would be extremely rude for a member of any class to misjudge the social rank of another by underestimating the number of his (dimly seen) sides, and so members of polite society cultivate the fine art of feeling each other's angles. One brief touch tells the in- formed practitioner of this subtle art the precise social standing of another. It may have delighted Abbott to mock the upper classes of nineteenth-century England by suggesting, in effect, that those of lower station grope about their figures to confirm their noble status. Undoubtedly, much of the amusement of Victorian readers sprang from the bizarre images suggested by a translation of Flatland social behavior directly into their own lives and times.

At the very lowest stratum of Abbott's two-dimensional society are the women, mere line segments, brainless beings given over entirely to the emotional side of life and incapable of the simplest logical deduction. A needle-shaped female represents the gravest possible threat to Flatland males through the possibility of piercing their sides by a careless movement of her posterior point. For this reason, the women are required to wiggle their posteriors back and forth so as to be periodically visible to all males in the vicinity. At the same time, they are required to utter little cries as a warning. Here is the clearest possible expression of stereotyped feminine Victorian behavior; the bustle, with its amplification of feminine anatomy, and the continual chatter, which Abbott implies is something to be avoided.

These examples suggest curious inversions in Abbott's way of looking at things: the substitution of touch fbr sight in the judging of one's fellows, as well as the interchanging of sexual roles in the act of "piercing" a member of the opposite sex. But more than this, the amusement occasioned by such imag- ery throws Flatland society and, by implication, Victorian society into critical relief The residents of Flatland seem made almost pathetic by a kind of double satire in which their imprisonment in the plane only magnifies their foibles: being silly is one thing but being silly *and* the object of inspection by more highly placed beings–that is, the Victorian reader–is quite another. In this sense Abbott goes somewhat further than Pope, the eighteenth-century satirist whom he most admired. For if Pope would suggest that

concern over a lock of hair is pointless, he offers no behavioral substitute beyond the im- plied "no". Abbott is suggesting that his own fellow creatures are not only given over to a trivial exis- tence but that beings of a higher dimension are (or could be) aware of it all. In short, the details of Flatland society and the immersion of Flatlanders in all its petty peculiarities amounts to a vast web of distraction in which Flatlanders are caught and thereby fail to realize their own vertical possibilities.

The logic of Abbott's two-edged satire therefore demands an element of sobriety when Mr. Square reaches out to the third dimension. Flatland can only be funny if Spaceland is serious, and Victorians read- ing this book may have glanced nervously about their room once or twice when Lord Sphere visited Mr. Square. Abbott may not have participated in the attitudes toward the social hierarchy, toward women, and toward the other elements of Victorian society satirized by his book, but he undoubtedly counted the attitudes themselves as of little moment when placed beside the Higher Reality implied by his mul- tidimensional framework. If silly, they were doubly silly, but even if absent, failure to appreciate this Reality was already a black mark against the uncaring denizens of Flatland.

Flatland begs some comparison with that other, better-known work of the Victorian imagination, *Alice in Wonderland*. Like Abbott, the author of the Alice books was a clergyman, Charles Lutwige Dodgson by name, better known as Lewis Carroll. While Abbott had received some mathematical training at Cambridge, Carroll was a professional mathematician. He taught mathematics at Oxford and even made a few minor contributions of his own in the field of logic. In Carroll the mathematical element predomi nated, in Abbott the spiritual.

The difference between the works reflects a differ- ence between their authors. To put it somewhat crudely, Abbott's purpose was to instruct by amusement while Dodgson's was to amuse by instruction. Once Abbott had generated interest and excitement in his bizarre, two-dimensional microcosm, he made it the vehicle for his metaphysical message. Dodgson's characters, on the other hand, were continually instructing Alice, either like parents or like teachers. Doing so, they expounded seeming nonsense. Abbott's spiritual preoccupations forced him to be serious on at least one level while Dodgson's mathematical profession seemed to have driven him to relief in pure fantasy with no obvious message at all–except, possibly, the message that there is no message, that life is ultimately lived down a rabbit-hole or through a looking-glass.

At the same time, no single group has cherished, preserved and even used *Flatland* and the Alice books as much as the scientific community has. Both books have been used regularly over the years to illustrate points of physics, mathematics, astronomy, and so on. I can almost hear one of my own professors explaining relativistic motion:

A particle approaching the speed of light must expend ever-increasing amounts of energy for ever-decreasing gains in speed. The situation reminds one of the Red Queen in one of the Alice books. She says, "It takes all the running you can do to stay in the same place."

or the structure of our universe:

One way to visualize four-dimensional space-time is to think of a two-dimensional space with an added time dimension. Imagine Flatland and its creatures moving through a third, time dimension and tracing Out world-lines as they go.

Like *Alice in Wonderland*, Flatland has inspired additional works, including *An Episode of Flatland*, published in 1907 by the American logician C.H. Hinton, *Sphereland*, published in 1965 by Dionys Berger, a Dutch physicist, and *The Planiverse* published in 1984 by A,K. Dewdney.

It is instructive to compare the two-dimensional worlds set forth in these books, especially the first two. As one becomes aware of alternative plane worlds, it becomes possible to ask "Which is more correct? What laws *ought* to hold in a two-dimensional universe and how would they influence its form and content? Would matter be possible and, if matter, would there (could there) be life?" An attempt to answer such questions can only be a project in scientific speculation since, obviously, no experiments can be performed. A speculator in two-dimensional science must make a few, simple assumptions and squeeze out of them the greatest number of interesting conclusions–an activity rather like mathematical research.

Abbott's world is seen as a flat, horizontal sheet within which his geometrical figures may glide in any of the compass directions. They know not of "up" or "down". Abbott's entire universe consist of this single, flat world. Mr. Square could presumably travel as far as he wished in any direction he chose. There is no gravity and there are no planets. To the uncritical eye such a world seems charmingly self-consistent and, therefore, believable. However, a closer exami- nation of the Flatland environment reveals some both- ersome defects: how do the Flatlanders move about within their realm? Even if Abbott had supplied them with limbs, it is not clear how they would propel themselves except by swimming through Flatland's air. How is Mr. Square's house anchored in place? in other words, while Flatland and everything in it are infinitesimally thin, zero-thickness in fact, it, in turn, must rest upon some kind of surface which acts as a support. Perhaps a kind of gravity causes Flatland to adhere to this surface and a kind of friction keeps houses in position. In any event, such an extradimensional prop would be a violation of the speculator's implicit rule that all phenomena in a two-dimensionpd universe shall be influenced, as far as possible, only by the laws of that universe, and no phenomenon may be explained by the intrusion or influence of phenomena adjacent to that universe.

Hinton's book, *An Episode of Flatland*, sketches a rather different universe featuring a flat, two-dimensional planet called Astria. As the Earth is a ball, so Astria is a disc and the Astrians may walk upon its circular surface just as we Earthlings walk upon our spherical surface. In order to walk, Hinton's Astrians come equipped with two legs and, except for two arms and two eyes, they are otherwise just as geometrical as Abbott's creatures. Hinton's planet is a great improvement over Abbott's world in at

least two respects. First it is the natural consequence of a few simple assumptions about a two-dimensional universe, namely that it has both matter and gravity. Second, the presence of a planetary surface provides a more physically reasonable stage upon which Hinton's tale may unfold. It seems a pity that, having gone to the trouble of setting up such a plausible world, Hinton should then condemn its charming inhabitants to a melodramatic plot involving the triumph of a socialistic revolt over totalitarian rule. Moreover, once he is fairly launched into his story, Hinton again and again ignores his physical premises with obvious blunders such as having a multitude of Astrians seated at a banquet table when it is not clear how more than two could dine at it–on at either end.

But Hinton, at least, had a clear grasp of a two-dimensional universe, for Astria circles a two-dimensional sun along with a companion planet called Ardaea. One can readily imagine other suns and other planets speckling the vast, two-dimensional sheet which is Hinton's universe. In fact, this very sheet may be curved into the form of a vast sphere and thereby form a model often used by cosmologists to explain the idea of an expanding universe. Almost twenty years after Hinton's book appeared, the astronomer Edwin Hubble discovered that our universe was organized into vast islands of stars–the galaxies–and that these islands were receding from each other at high speeds. The universe was expanding, but not in a way comprehensible to the man or woman in the street. For this reason, our three-dimensional universe was sometimes represented as the two-dimensional skin of a balloon speckled with galaxies: as the balloon was inflated the galaxies were all clearly seen to recede from each other, an image jocularly referred to by astronomers as "Hubble's Bubble. "

The third book on two-dimensional worlds to appear was Dionys Berger's *Sphereland*, a novelistic exposition intended for the general reader interested in science. Berger uses the spherical universe we have. just discussed to explain the curvature of space in our own universe as well as other physical and cosmological ideas. In this book residents of Flatland set out to discover whether their universe is curved by measuring the angles of an enormous triangle, two points of which can only be reached by spaceship. They find that the sum of these angles is greater than one hundred and eighty degrees, good evidence that the triangle lies within the surface of a sphere.

Berger allows for the possibility of space travel by giving Flatland the shape of a disc and then embedding it in his spherical universe. Flatlanders, in traveling to the'edge of this disc, notice that the misty Flatland air becomes increasingly rarified and they may then see through it, out into the vastness of their plane universe, catching their first glimpse of stars, as it were. By this clever but somewhat tortuous device Berger is able to use the reader's familiarity with Flatland in order to extend Abbott's tale to an account of Mr. Square's grandson, a clever hexagon who takes part, ultimately, in the ambitious space curvature project.

Berger did not much advance the art of designing two-dimensional universes, beyond noticing that they could be curved and that their inhabitants would be able to measure

such curvature directly. However, Berger did introduce a number of strange beasts into Flatland and displayed a primitive spaceship as well as a net for it to land in.

The fourth book on two-dimensional worlds, Dewdney's *The Planiverse,* describes how a class of computer science students accidentally contacts a two-dimensional world on their computer. The students had been developing a program to simulate events in a very simple two-dimensional universe of their own design, focusing on a planet they called "Astria" after Hinton's world. Suddenly one evening one of their simple, geometrical creatures began to say things outside the program's scope. It announced itself to belong to a world called "Arde," and soon thereafter the simple Astrian was transformed on the display screen into an outlandish creature of incredible complexity: the student simulation program had somehow fallen into lockstep with the real thing and the computer had been converted into a communication tool for exploring Arde and its inhabitants. Over the course of one summer the students followed the adventures of one "Yndrd" in his quest for the Beyond.

Arde is a direct extension of Hinton's planet, taking its name, in part, from Astria's sister-disc, Ardaea. It circles its own disc-shaped sun which, in turn, is one of the innumerable flat stars in one of the innu- merable flat galaxies comprising the "Planiverse", Dewdney's name for his own, particular, plane universe. The details of Arde and the Planiverse were worked out largely by Dewdney but not without some help from dozens of scientists and laypersons worldwide, who sent him everything from technical papers on two-dimensional atomic structure to de- signs for planar machines. These submissions were all in response to an article in the July, 1980 issue of *The Scientiftc American* in which Martin Gardner presented some of Dewdney's ideas regarding the possible existence of a two-dimensional universe.

The question of the existence of a two-dimensional universe, even in theory, embodies some very weighty philosophical and scientific issues. For example, is there some definite reason why our own universe has three physical dimensions? Roger Penrose, the English mathematical physicist, feels that this is an important question whose answer may well involve theorizing about the ultimate structure of space. In a more' general vein it may be asked, "What is the relationship between the laws of our universe and the fact that it exists?" Does the universe give rise to its own laws or *vice versa*? Given its laws, does it exist because in some mathematical sense it *must*, or does it exist as the creation of some "outside" agency? This question was one that Einstein often pondered, and it becomes more immediate when we investigate the possibility of actually designing a universe different from our own, No matter how far we succeed in the attempt, how should we ever actually *construct* one? Such questions, one feels, bring us to the limit of what is humanly feasible and we turn to our own world once more with a strange, new respect for the mere fact that it exists!

And now to Flatland, that strange and charming nineteenth-century tabletop microcosm, source of speculation, and mirror of metaphysics.