The Curious Creativity of John Horton Conway

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Abstract

In 2007, the author embarked on a biography of Princeton mathematician John Horton Conway. She soon learned that her subject would test her creative mettle as a writer and artist. The charming anarchist that he is, Conway would push the boundaries of literary convention and the art of writing biography. A talented storyteller himself, he required an experimental approach in the telling of his life story. What resulted was a "meta-biography," wherein the narrative is passed back and forth between subject and biographer, in order to accurately capture the artful nature of Conway's ingenuity, both in terms of his personality and his own creative works. Herein, as an adapted sampling, the author recounts her process, as well as what resulted in describing some of Conway's more eccentrically crafted contraptions, mathematical, whimsical, comical, and otherwise.

Figure 1 : *John Conway in his Princeton office, circa 1993. Photo © Dith Pran*

Introduction

Mathematics is wedged uneasily between the sciences and the arts, and within the discipline there are artists and there are scientists. John Horton Conway is an artist.

Spending the first half of his career at Cambridge and the second half at Princeton, Conway gained a reputation as a true original. He is utterly *sui generis*. I came to think of him as Archimedes, Mick Jagger, Salvador Dali, and Richard Feynman all rolled into one—a singular mathematician, with a rock star's charisma, a slyly bent sense of humor, a polymath's promiscuous curiosity, and a compulsion to explain everything about the world to everyone in it.

He first found fame when he discovered the Conway groups in mathematical symmetry. Next he invented the aptly named surreal numbers, and then the cult classic Game of Life. More than a cool fad, Life demonstrates how simplicity generates complexity; it provides an analogy for all mathematics and the entire universe. He accomplished all this circa 1970, which he calls his *annus mirabilus*. In writing his biography [1] and recounting these among a myriad of Conway's achievements, I discovered that Conway is also a masterful storyteller — he has perfected the art of spinning a tale, drawing people in, and holding them enrapt while he buttonholes them with exposition on his latest mathy obsession. That is certainly the effect he had on me as his biographer.

As a result, the process I devised in researching and writing the book was as follows: I interviewed Conway and recorded his tales with a digital tape recorder, which he came to refer as "that damned contraption." All the same, he gamely sat for innumerable interviews. After each round on a given topic, I transcribed hours upon hours upon hours of Conway talking (he is a talker, not a listener). I then used information gleaned as fodder in constructing two components of the biography's narrative. First, I used historical information "on background," so to speak, and then employed a third-person narrator for recounting the broad strokes of his life, as well as for relaying the many non-mathematical anecdotal yarns that are part of Conway's repertoire, and the aspects of his life that are most accessible to the general reader. Second, once I had set the scene with historical contexts and colour snapshots, on occasion I passed the narrative to Conway, usually for the purposes of explaining something that was mathematical in nature. Conway is a consummate explainer and popularizer—there was no point, nothing to be gained and everything to be lost, in his biographer attempting to paraphrase his eloquent expertise. In the examples that follow in sections below, the passages cast with sans serif font are quotations from Conway, carrying forth in his typically extended style (italics are traditional for extended quotations, but there is nothing traditional about Conway; his style is more bold and bald, simple and straightforward; plus, italics are notoriously difficult to read).

Having honed in on this process, composing the overall arc of the biography was far from a linear undertaking. I circled around my subject for years, trailing him on international trips and during his daily routine in Princeton, gradually attaining and accumulating what I hoped would be an accurate and captivating portrait. The process became almost sculptural in methodology. I finely and carefully chipped away at the raw material, revisiting the same topics with Conway again and again and again, reorganizing the at times impressionistic collage in my mind and on the page, molding it into a simulacrum of the man, the mathematician, before me.

Furthermore, it is interesting to note that Conway himself possesses an artist's sensibility in his multi-media approach to explaining his mathematical gems. He is not *trying* to be an artist; he does not *formally* have artistic motivation — but this does not diminish the sense of artistry that he exhibits. Conway has been known to carve a turnip into a dodecahedron, to fashion a Klein bottle using a quilting of iron-on patches, swaths of bandages, and a zipper that allowed the bottle to unzip into a Möbius strip. His office is always a full-blown mess (see Figure 1), filled to the brim with models made from scratch from pencils, bicycle tire spokes, and a rainbow array of coloured cardboard. But the two contraptions that, in my view, truly prove his chops as a mad mathematical artist are his water computer and his 4-dimensional helmet.

The Water Computer

Figure 2 : *Conway and WINNIE, circa 1957.* Photo courtesy of Peter Evennett.

When Conway was an undergraduate at Cambridge, he and his chums spent an afternoon or two walking about town, along the cobblestoned Trinity Street in October 1957, putting up posters announcing WINNIE IS COMING! The posters went up along King's Parade, Trumpington Street, the fence around Great St. Mary's Church, and scattershot about town: WINNIE IS WAITING FOR YOU —WATCH OUT FOR WINNIE!— ARE YOU READY FOR WINNIE?

This was two decades or so after Alan Turing booted up the computer age with his Automatic Computing Engine, aka ACE, and from there the computer's lineage degenerates into a tangled timeline of acronyms: ENIAC, EDVAC, EDSAC, MANIAC. And then Conway contributed WINNIE, a water computer (see Figure 2), a "Water Initiated Numerical Number Integrating Engine." Though it's unlikely it was "Numerical Number"; perhaps it was "Water Initiated Nonchalantly Numerical Integrating Engine," or some such. Conway designed WINNIE based on his close observation of urinal-flushing mechanics. Standing about six feet tall, she was engineered from plastic cups, siphons, and circuitous plumbing.

How it worked was this: Standing on the stool, I'd pour 1 unit of water into the cup at the very top. This cup would then be ½ full, and the water would just stay in there, and that indicated the binary notation "1" and registered the numerical value 1.

Then I'd pour in another unit of water into the same cup, filling it up and causing all the water to run out via a little tube halfway up at the side of the cup—that's how a siphon works, when the water starts moving out all of it flows out, and it would all runneth over, ½ of it going into the cup waiting below, indicating now the binary notation "10," for the numerical value 2. Pour in another unit, and the first cup again registered "1" and the second still holds "1," which gives us a grand total of "11," or 3. Another unit made the first 2 cups empty with the third cup registering "1," giving 4. And so on. WINNIE could count to 127, or 64 + 32 + 16 + 8 + 4 + 2 + 1, or 1111111.

She could also add and multiply. Though as soon as the product of any calculation exceeded her limit, she started peeing—and in fact she peed off ½ a cup when any cup received its second allotment and ran over to the next cup, that was the operating principle. But the peeing happened en masse at the

end. All at once all the cups would runneth over in a domino effect waterfall, emptying all the cups and clearing all the reservoirs to 0 as all the water flushed into a holding tank on the floor. At least that was where the water was supposed to go.

There was the unfortunate incident when Conway exhibited WINNIE at the Societies' Fair, the annual fall fair where the university clubs showed off their wares in the hopes of recruiting new members. Conway belonged to two Cambridge clubs: the Archimedeans, the university math club, and the New Pythagoreans, the math club associated with his college and about five other colleges, including Girton, a women's college (there were four at the time).

That's important, the girls. We had to pull in some girls!

Conway and his water computer represented the Archimedeans at the fair, though the unfortunate thing was that WINNIE peed and caused a flood and destroyed a nice piece of the Guildhall's parquet flooring. The Societies Fair was thereafter held elsewhere, in the Corn Exchange. But WINNIE was a popular exhibit, earning a write-up in the Cambridge newspaper. She was a "proof of principle" experiment, an experiment conducted to see if one of Conway's harebrained ideas was workable. Hypothesis: If a urinal-flushing doohickey is properly repurposed, it will power a binary computer. Conclusion: Yes indeed, it will.

The 4D Helmet

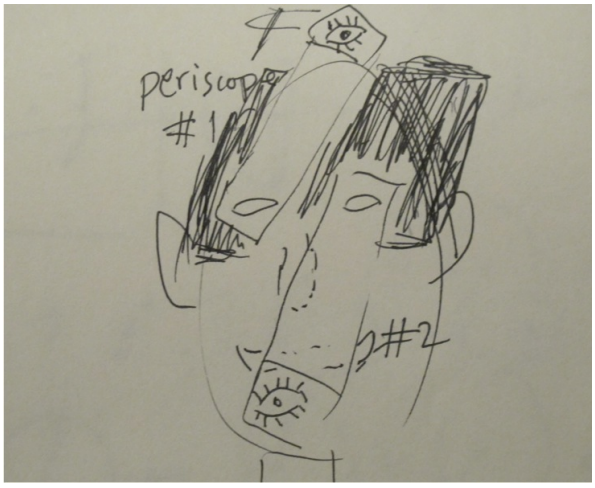

Figure 3 : *Conway's rendering of his 4-dimensional helmet, circa 2010.*

Over the course of his career, Conway has spent a good amount of time in dimensions greater than three. He cultivated this slippery grip on reality in the solitude of the Sidney Sussex Fellows Garden at Cambridge. The garden path itself was slippery, the summer's overripe mulberries, heavy with juice, having taken their Newtonian plummet. They made a mushy purple mess underfoot as Conway perambulated contemplatively, and tentatively, wearing a clunky contraption on his head with gangly protrusions emanating from his eyes (see Figure 3). While this headdress obscured Conway's view of the mundane 3-dimensional reality, the gadget's purpose was that in doing so it would enhance his ability to see a more awe-inspiring 4-dimensional world.

Seeing multidimensional things has been a slight obsession with me all my life. Or at least apprehending multidimensional things, comprehending them, studying them.

But ask Conway how precisely one intuits 4 dimensions, and depending on his mood he might respond:

None of your business! That's personal!

More likely, though, he'll tell the long story of how he tried to train himself to see four dimensions. The first step in his scheme was to coax his faithful friend Mike into making a few short films that would expand the bounds of his spatial perception by depicting computer-generated vignettes of geometrical entities, cubes and so forth, as they rotated and reflected through 4-space. Conway stared at these images and waited for levitation. Nothing happened. His retina was too accustomed to seeing two dimensions and inferring three, and from there it couldn't easily extrapolate to four. This is what prompted him to get crafty and construct an assistive device, his hyperspace helmet.

Toward the end of a research trip to Cambridge, Conway and I visited the Sidney Sussex Fellows Garden. The mulberry tree was still there, and the garden as a whole had changed little, although now it was open to the public.

This used to be all locked away, closed to visitors. And you see, it's enclosed by this high wall so nobody can see in. And moreover you can't do too much damage to yourself. I was worried about that. You realize, these weren't glasses I was wearing. It was a complicated helmet with periscopes on it. Let me draw you a picture …

You see, my idea was that under normal circumstances our eyes, each eye, sees a 2-dimensional picture. But the 2 pictures differ by what's called parallax, which is always horizontal parallax because your eyes are spaced horizontally apart. If you close your right eye and look at that mulberry tree with your left eye—or you can do it by holding your index finger out in front at arm's length—and then close your left eye and look at it with your right eye—it appears to shift its position slightly, it moves back and forth. That displacement is horizontal parallax.

The point is, we only have a 2-dimensional retina. We have this built-in visual system that can only see 2 dimensions. Each eye sees a 2-dimensional picture and then we get some kind of partial vision of 3 dimensions by having these 2 different eyes which see 2 slightly different pictures that differ ever so slightly by a horizontal parallax. So I had this great idea of using the notion of "double parallax" to see 4 dimensions. Your left eye's picture and your right eye's picture theoretically could differ not only by horizontal parallax but also by vertical parallax. That makes 4 positions, which would give your eyes the input they need to see in 4 dimensions.

And what generated the vertical parallax was the helmet. I made it out of a crash helmet, cut various bits off, bolted on a visor, and put these army surplus periscopes in place. One of them moved my left eye diagonally downward to the middle of my chin, and the other moved my right eye diagonally up to the middle of my forehead. The net effect was that my eyes were displaced vertically, and to rather more than the usual horizontal displacement, about twice as much.

And then what I did was I just walked around in the Fellows Garden for a few hours every day when I could spare the time. And I gradually got accustomed to vertical parallax, to seeing the mulberry tree displaced vertically instead of horizontally.

There was also the famous day, or famous for me anyway, when I decided I was going to walk out in public, in the center of town. I'm pretty sure it was a Saturday. If I deliberately chose Saturday, I was a fool, because you know there were throngs of shoppers. The streets were crowded. I was getting in everyone's way and people were gawking and kids were yelling, "Mummy! What is that?" When I went out there with this strange helmet on, it was harder. But when I was walking around in here it was all slow motion; nothing was moving, and I could stop and study what things looked like with vertical parallax.

And then my idea was that I would try viewing the 4-dimensional pictures in the films again, using horizontal and vertical parallax. To get my eyes used to it I practiced switching back and forth from horizontal to vertical parallax while I walked around here in the garden. I needed to know that the horizontality wasn't hardwired in. I was unsure as to whether the eyes could be trained to interpret vertical parallax at all. I needed to know that the brain would accept vertical parallax. And it did.

And then after all this training to see vertical parallax, I took the helmet off and watched the film again—trying to use both horizontal and vertical parallax at the same time on my own. But you know, it was a rather coarse pixel screen, and the pictures were rather small, not very well done, and the whole thing really died because this little computer-generated movie wasn't much good. So it didn't really work. I mean, yes, I did see some sort of 4-dimensional stuff. But I think of it as the 4-dimensional fiasco rather than a great success.

Or, as he's at least once put it slightly more optimistically:

I suppose I had a limited amount of success in that quixotic quest. I could see 4 dimensions because I just got used to thinking that way. But there was no hope of going beyond, so what's the point?

At this stage in his career, Conway didn't consider polytopes and this foray into hyperdimensional space as being his quote-unquote "job." Later it would become a more professional undertaking, which he would explore by more conventional means, and going well beyond 4 dimensions, initially to 24 dimensions with his Conway group, later to 196,883 with the Monster group, and all by brute-force brainpower.

Conway never tried LSD, known to induce intensified visual impressions and shape shifts. Nor did he eat any magic mushrooms and converse with his geometric friends. And he does Bill Clinton one better, claiming that he doesn't even know what marijuana smells like. Despite coming of age in the sixties, the permissiveness of the prevailing culture never persuaded him to do drugs—he was the straight hippie, in that sense. He is the first to admit he wasn't nearly so unimpressionable in the sexual realm.

That might seem a rude and abrupt place to conclude. But so often in weaving together Conway's stories there was nary a segue with which to stick together all the ideas that he tossed forth in such bewildering profusion. On the whole, like the numbers he invented, Conway himself, the man and the mathematician, can perhaps best be summed up as "surreal"—he is an avant-garde iconoclast possessing an inimitable facility for expressing the mathy passions and all manner of nerdish delights that populate his amazing otherworldly world.

References

[1] Roberts, Siobhan. *Genius At Play, The Curious Mind of John Horton Conway*. New York: Bloomsbury USA, 2015.