Between Atom and Adam

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One July morning in 1945, just before sunrise, US Brigadier General Farrell (of Manhattan Project fame) wrote to his Army superiors to inform them that the Trinity Test had been successful. Still in awe of the explosion he had witnessed, he recalled that "the whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray, and blue. It lighted every peak, crevasse and ridge of the nearby mountain range with a clarity and beauty that cannot be described but must be seen to be imagined" ("Chronology"). Light—the universal symbol of knowledge, growth, and hope—had become a harbinger of destruction. It was a moment of victory for science, just as it was for the Allies: never before had human beings demonstrated such control of nature on such an extreme scale. The promise of Einstein's $E=mc^2$, the release of an unimaginable quantity of energy from just a few grains of matter, had at last been fulfilled.

Einstein's famous equation has been the subject of innumerable speculations and imaginings since he published the theory of special relativity in 1905. In one such musing, "The Brain of Einstein," philosopher Roland Barthes seeks to reconcile two prevalent, seemingly paradoxical visions in the "popular imagery" of Einstein (2): one complex, mathematical, and mechanical, the other given to mysterious immediacy and a wizard-like simplicity. Barthes ultimately suggests that the combination of both these characterizations is what "fulfills all the conditions of myth, which could not care less about contradictions" (3), and transforms Einstein from man into legend. The $E=mc^2$ relation thus reflects Einstein himself: it too combines two opposites in a single astonishing result which, "by its unexpected simplicity, almost embodies the pure idea of the key . . . opening with a wholly magical ease a door which had resisted the desperate efforts of centuries" (2). Ironically, its simplicity has enabled it to be integrated so effortlessly into common knowledge that one often forgets how beautiful a diminution it really is. Compared to most equations in physics, $E=mc^2$ is remarkably short. It consists of only five symbols—and each of them familiar, for it contains none of the Greek widgets and cryptic operators that keep most science shrouded in the veil of mystery. Mathematically, too, $E=mc^2$ is one of the simplest possible functions, entirely one-dimensional, involving only two variables and an arbitrary constant.

Though these simplicities may account for its popularity, they hardly conjure the "magical essence" of which Barthes speaks; $E=mc^2$ is not simply a small collection of familiar symbols, but, like Barthes's vision of discovery itself, "is simple like a basic element, a principial substance, like the philosopher's stone" (2). Most science textbooks I have read refer to alchemy as a sort of shameful academic sin, a pseudoscience, something to be swept under the rug of history and hidden there; I have even heard scientists lament that Newton, the father of Dynamics, dedicated so much time to the search for the philosopher's stone, *lapis philosophorum*, which would turn lead into gold and bring limitless life and enlightenment to its inventor. Yet by 1919, Ernest Rutherford had realized alchemy's age-old dream: he shattered the immutability of nitrogen gas with a stream of alpha particles. For his efforts, Rutherford received the nuclei of oxygen and hydrogen, while the rest of humanity received an upsettingly simple demonstration of nuclear transmutation and the photoneutron effect. It was $E=mc^2$ that foreshadowed and verified the result. Immediately following the first transmutation, a storm of research confirmed that man could manufacture one element from another, even turning lead into gold. I'm told that this process didn't turn a profit, à la Nicholas Flamel, but I believe we did profit in a different way. We learned about change: atom to atom, speck of dust to spot of light and back to dust again. We learned, in nuclear transmutation, the fundamental unity of all matter and energy. In finishing this game of "connect the dots," $E=mc^2$ represents for us the fulfillment of Newton's dream and science's promise.

One of the most striking images of simplicity that I have ever seen was featured in physicist Murray Gell-Mann's attempt to explain his way from the realm of subatomic particles to the visible, experienceable universe. Quarks, the small, secretive, simplest constituents of matter, are scattered sparingly in empty space—yet in the jaguar, that terror of the nocturnal jungle, these unsolid quarks form agonizingly solid teeth! The solution to the solidity paradox is, of course, mutual repulsion by same-charge electric fields of atoms: energetic messages carried between nuclei by photons, those same particles that bring us the heat and light of sunrise. Yet Gell-Mann wants not only to understand our perception of the jaguar, but also to explain how supposedly simple particles can give rise to speed, spots, and a keen predatory instinct.

To shed some light on the quandary, Gell-Mann introduces a graphic, titled simply "Some patterns of connection of eight dots," which displays 6 various line-and-dot configurations (31). He challenges the reader to identify the simplest and most complex configurations and waits with a professorial smile for the reader to realize that it's a very nasty 'trick question'—one that, after years of mental acrobatics, I still cannot answer definitively. At first, I saw A as the simplest and F as the most complex. Predicting my selection, Gell-Mann suggested I reconsider. "Isn't the property of having all dots connected just as simple as that of having no dots connected?" he proposed (31). Feeling somewhat ashamed of my simple-mindedness, I began the search for a new recipient of the complexity award.

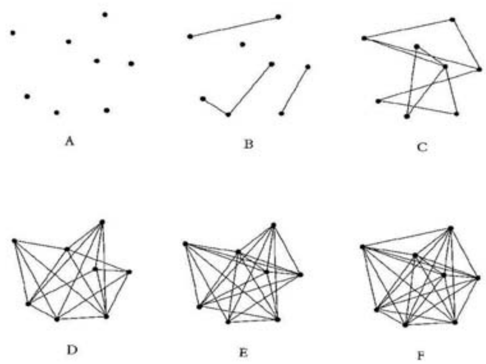

Figure 1: Some patterns of connection of eight dots. (Gell-Mann)

B looked promising, having a totally entropic arrangement of lines and dots. If, however, one were to categorize the configurations based on the total number of objects they contained, B would be the simplest, containing four line segments and one dot to A's eight dots. Worse and worse! I then realized that E was the precise inverse of B. I found myself laughing, my confusion and my merriment increasing at each new discovery. Laughing perhaps because I had been fooled, and perhaps because of the impossibility of it all: you know the answer, you think again, you think some more, and when you're done thinking you 'know' less than you did before you began.

Gell-Mann's query reveals that there remains something tricky, even mysterious, about simplicity itself; even simplicity is not so simple. He ultimately suggests a standard of Algorithmic Information Complexity (AIC), in which the time it takes to describe something determines its complexity—but this answer is not entirely satisfying, for AIC clearly depends upon the words and syntax available to the describer. Thus Gell-Mann does not so much solve the problem of our perception of simplicity as much as shift the responsibility to language.

Yet words scarcely seem more straightforward than dots and lines. In "Craftsmanship," a Virginia Woolf essay that toys with the slippery reduction of ideas into words and words into symbols, we are advised that words are like water, "lapsing and flowing into each other like reeds on the bed of a river" (635). As I write Woolf's words, I'm reminded of Heraclitus's infamous pronouncement that 'one can never step into the same river twice.' All the world is in flux, and so must be the language that describes it. Like water, words expand to fill a vessel of any shape or texture; they transform effortlessly from solid to liquid to vapor; they are never truly still—such are the entropic forces of nature and of humanity. Attempting to avoid the confusion associated with complex "sunken meanings," Woolf turns to the simple "language of signs," in which one star signifies "good," two mean "better," and three denote "best" (634). "With a handful of stars and daggers," she postulates, "the whole of art criticism, the whole of literary criticism could be reduced to the size of a sixpenny bit" (634). The language of symbols—of stars and dots—cuts through nuance with pointed accuracy, and turns to "multitudinous seas . . . incarnadine," as if with the blood of "sunken meanings" pinned down by the daggers of human reason (635).

We are thus left with two conflicting conceptions of beauty: the irreducible simplicity of Einstein's $E=mc^2$, and the irreducible complexity of Woolf's language. It seems to be our task as thinkers to move back and forth between them: the incorporeal uncertainty of idea, locked within a single mind, must be cast in bronze for all to see before it can complete its work in the world. Only by transfixing words, by damming up their stream, can we shape and organize them "so that they create beauty, so that they tell the truth" (Woolf 636). Yet I have found that beauty of a simple, describable kind is as slippery as its complex counterpart.

One carefree summer day, enjoying the shade of one of upstate New York's grander scrub oaks, I felt inspired to try my hand at sculpture. Though I had received a small kit as a present one childhood Christmas, my interest had not endured any longer than it took to unwrap the package. Now, amongst the depths of my bedroom drawer, I found the heavy blue box emblazoned with the silver lettering "The Metropolitan Museum of Art" and beneath that, "the art of sculpting." Inside the box were a mallet, two fine chisels and a block of some jade-colored, almost translucent stone. It seemed a work of art in itself! I resolved to make something beautiful, something liberating: a bird. Recalling what I had read of Michelangelo and Donatello, I tried to see the bird in the stone—in the shadowing, in the veins of imperfections. I chiseled patiently for over an hour, and was rewarded by the rough outline of a wing. I was stunned when, after a few more careful taps, the wing broke off with a disheartening crack.

No matter, I reasoned, I'll simply make a smaller, simpler bird! A new wing and neck had been extracted from the stone when the emergent form suffered another mishap. Again the remaining stone was resurfaced, again I began to remove chips of stone—and so the process continued until the block of stone that remained was so small that I could no longer see the bird inside. My experiment with sculpting was over; I was tired, resentful, and distressed. I had spoiled a pristine block of stone, which, by my efforts, was now reduced to a heap of translucent green gravel on the floor of my porch. Worse, there was no bird and no beauty. It seemed to me that sculpture was a most destructive art, requiring the reduction of nature in order to reach a final product. I thought the whole process most unjustified, and never took up a chisel again.

According to his essay "The Bird of Paradise: The Hunter and the Poet," Edward Wilson faced a similar difficulty accounting for beauty in his trek through the Huon rainforest. As an adventurer searching for the rare Emperor of Germany bird of paradise, he hoped only to catch a glimpse of its "dazzling ornaments" and to hear but a few bars of its "bubbling and flute-like notes"—yet as a biologist, Wilson expressed the hope that he would "be able to dissect and understand this machinery at the level of the cell" (112). We were much alike, Wilson in the rainforest and I on my porch, for both sculpting and genetic mapping require what Wilson terms "reducing nature," he with his scalpel and I with my chisel. In breaking down, we precipitate our respective "artlike intuitions" (112). Wilson, however, acknowledges the fear that in our search for understanding, nature "can be mechanically reduced to the level" that we no longer see the bird itself (113). Such a robotic treatment of the objects of our fascination might oversimplify the world, failing to capture the true character of beauty, merely reducing it to its constituent dust. "One speaks of [Einstein's] thought," muses Barthes, "as of a functional labor analogous to the mechanical making of sausages, the grinding of corn or the crushing of ore" (1). All three take whole, natural substances—animal, vegetable, and mineral—and pulverize them into tiny pieces to be bagged, re-forced, and packaged.

A philosophy professor I once knew told me that all thought involves breaking the unity of existence with the knife of logic. From nature to final product, the act of creation is an act of division, of cutting, of violence. The wave patterns of Einstein's brain will be "all the more violent" (1), Barthes tells us, because Einstein is a more powerful thinker. Such brutality to nature is even inherent in the study of physics itself: the primary tool of the nuclear researcher, innocuously named "particle accelerators" by physicists and "atom smashers" by the public, are literally tools of destruction. "[I]t will at last be possible to dismantle" even Einstein's brain, in order to conduct the same sort of research upon it that Einstein himself conducted upon the world (1). Thought, it seems, is a kind of violence. And behind such thought looms the memory of the destruction Einstein's violent thought "unleashed" (3): one of his little sausages, as it were, blew up over Hiroshima in the most devastating moment humanity has ever had cause to celebrate.

I cannot help but shake my head in wonderment. Is this the "diabolical power" of which Woolf speaks (635): that "mysterious property" of words (635), of equations, of constellations of dots, through which "the world blissfully regains the image of knowledge reduced to a formula"? (Barthes 2). The mystery is in the moment: the moment of simplicity before entropy, the moment of intuition after reduction, the moment of silence before the explosion. But I am—we are—never truly "done thinking," never rewarded with a final product. For if eight dots on a page confound us, then what kind of enlightenment can we hope for concerning the innumerable particles of the universe? According to Barthes, we must be willing to accept "the most contradictory dreams," a compromise characterized in Barthes's writing by a shift from extensive semicolons to whole, comma-ed clauses (3). Similarly, Woolf advises us that "truth . . . is many-sided, flashing this way, then that" (637). It flickers in and out of existence, like photons flitting across the darkness between atom and Adam—solidifying, illuminating. Wilson, too, perceives that upon "reconstitution through a synthesis of all the hard-won analytic information . . . misleading illusions have given way to more comprehensive light and wisdom" (113). Yet this light, the light of General Farrell's nuclear dawn, sears even as it illuminates. Einstein's "key" may have been simple, but the door it opened was of unimaginable complexity. Yes, General Farrell, the Trinity Test was a success.

"And yet," Barthes recounts, "some failure on the part of Einstein is necessary: Einstein died, it is said, without having been able to verify 'the equation in which the secret of the world was enclosed'" (3). $E=mc^2$ epitomizes symbolic reduction. There was even hope, as Gell-Mann points out, that Einstein's energy-matter relation would advent the long-sought 'Theory of Everything,' upon whose discovery physics would be over and humanity would be done thinking, forever. In his later years, Einstein himself published a set of equations that claimed to accomplish that task, but they were soon demonstrated to be inadequate, prompting Gell-Mann to write that "the greatest physicist of modern times had lost his powers" (126). To some degree, we all experience the same unavoidable failure—with dots, with words, with stones. Yet for all the inevitability of failure, physics seems to me a glorious quest. The secret of the world was hardly opened. But it *was* opened! One man even got a look inside. For that euphoric moment, I would give a lifetime.

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