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All At One Point: The New Physics of Italo Calvino and Jorge Luis Borges

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ALL AT ONE POINT:

THE NEW PHYSICS OF ITALO CALVINO AND JORGE LUIS BORGES

Mark T. Rinaldi

A DISSERTATION
SUBMITTED TO THE GRADUATE FACULTY
IN COMPARATIVE LITERATURE IN PARTIAL FULFILLMENT OF
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Abstract

ALL AT ONE POINT:
THE NEW PHYSICS OF ITALO CALVINO AND JORGE LUIS BORGES

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This work of comparative literary criticism focuses on the presence of mathematical and scientific concepts and imagery in the works of Italo Calvino and Jorge Luis Borges, beginning with an historical overview of scientific philosophy and an introduction to the most significant scientific concepts of the last several centuries, before shifting to deep, scientifically-driven analyses of numerous individual fictions, and finally concluding with a meditation on the unexpectedly fictive aspects of science and mathematics. The close readings of these authors’ fictions are contextualized with thorough explanations of the potential literary implications of theories from physics, mathematics, neuroscience and chaos theory. While the mathematical studies highlight concepts such as “Zeno’s Paradox,” Cantorian set theory, and representations of numerical infinity, the discussions of physics isolate theoretical structures such as black holes, parallel universes and quantum-entangled particles for use in discussing the fictions of both authors.

Underlying the main goals of this work is an equal focus on the existence of an “ideal intellectual” or, more broadly, an ideal liberal arts education that draws together concepts from diverse and seemingly-unrelated fields of knowledge with the intention of generating unexpected
and novel ideas and connections. By demonstrating the numerous appearances of scientific and mathematical imagery in the works of Calvino and Borges, this work emphasizes the shared fictive basis of all human knowledge and strives to set science and fiction alongside each other as equals in the hope of preserving the richness and diversity of intellectual enterprises.
To Carter, the only one, my everything, my infinite

To Giancarlo, for his patience, kindness and support

To Marjorie, who taught me how to breathe

To my mother, father and sister, for their sacrifices, humor and love
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**Introduction – “The Two Cultures”**

In 1959, the British chemist and novelist C.P. Snow presented a controversial lecture entitled “The Two Cultures,” which condemned the gulf separating scientific disciplines and the humanities. From the start, Snow established himself as a member of both groups, or rather as an intellectual who dwelt in the center of this expanse. “By training I was a scientist: by vocation I was a writer. That was all.” (Snow 1) Citing the British educational system’s failing in over-emphasizing humanities studies at the expense of scientific advancement, Snow lamented the negative consequences of such a single-minded approach to knowledge: “This polarisation is sheer loss to us all. To us as people and to our society. It is at the same time practical and intellectual and creative loss, and I repeat that it is false to imagine that those three considerations are clearly separable.” (ibid. 11) Snow’s lecture went on to skewer the rigid physical scientist and the huffy Shakespearian alike, indicting both for their closed-mindedness and refusal to see the merits of any discipline outside of their own.

Snow concluded his lecture with the postulation that

the clashing point of two subjects, two disciplines, two cultures – of two galaxies, so far as that goes – ought to produce creative channels… Of course, that isn’t the way that science could be any good to art. It has got to be assimilated along with, and as part and parcel of, the whole of our mental experience, and used as naturally as the rest. (ibid. 16)

This desire to merge not only the two “cultures” of science and art but all forms of human knowledge into one integrated, generative continuum is echoed in the writings of the Italian writer of fiction, Italo Calvino, and his Argentine inspiration and contemporary, Jorge Luis Borges. The study that will follow is an attempt to define and expand the existing body of research on the interdisciplinary approaches of both of these authors, with a particular focus on their employment of scientific and mathematical themes within their fictional and non-fictional
works. By drawing together a diverse group of studies of Calvino and Borges undertaken by scholars of both “cultures,” as well as establishing a strong foothold in the scientific and mathematical theories of their time (and ours), we can hope to explicitly define the role of interdisciplinarity in each of these authors’ literary and personal philosophies. In doing so, we will reshape the image of the ideal intellectual as one who is equally versed in scientific theories and literary traditions, rooted firmly in methodological rigor but empowered with the agility to creatively harvest inspiration from any form of human knowledge.

Calvino’s Call to Interdisciplinarity

Italo Giovanni Calvino Mameli was born in Santiago de las Vegas, Cuba, in 1923, to scientist parents. Soon after his birth, his family relocated to San Remo, Italy, which was Calvino’s father’s ancestral home and where his parents would cultivate and study a large variety of exotic fauna on a large estate. Calvino later recounted his childhood experiences in a piece entitled “Personal Portrait,” eventually published in a biographical collection entitled Hermit in Paris. “I am the son of scientists: my father was an agronomist, my mother a botanist; both were university professors.” (Calvino 13-14) It might have seemed reasonable to expect that Calvino would follow in his parents’ footsteps, but that was not to be the case. “After secondary school I made some attempts to follow the family’s scientific tradition, but my head was already full of literature and I gave up.” (ibid. 14) This departure from the family’s preferred occupation placed Calvino in a lonely position, especially since his only brother would go on to become a noted geologist. Calvino notes in Six Memos for the Next Millennium that “…in [his] family, a child could only read educational books, particularly those with some scientific basis.” (Calvino 35) The force of his family’s push to promote scientific studies is given some justification in another
discussion about his life, this time in *Una pietra sopra*, a self-curated collection of Calvino’s essays and media articles.

Tra i miei familiari solo gli studi scientifici erano in onore; un mio zio materno era un chimico, professore universitario, sposato a una chimica; anzi ho avuto due zii chimici sposati a due zie chimiche [...] io sono la pecora nera, l’unico letterato della famiglia. (Calvino XIV-XV)¹

Despite being considered a “black sheep,” Calvino did not give up all scientific studies. In fact, as he mentions in *Hermit in Paris*, he did make an honest attempt to become a scientist before committing himself fully to literary pursuits. He elaborates on these experiences in “Behind the Success,” another essay taken from the same volume.

…After getting my school-leaving certificate I made a choice which might have seemed, and perhaps was, determined by my family background, and enrolled in the Agriculture Faculty of Turin University where my father had taught up until a few years previously (he had retired by now) courses on ‘Tropical cultivation’ and ‘Tree-growing’. What I had in mind was that for me writing could be a side-line to a ‘serious’ profession: the latter would keep me in touch with reality and let me travel the world, like my father who had spent nearly twenty years of his life in Central America, and had lived through the Mexican Revolution. This attempt at realigning myself with a family tradition did not work, but the basic idea was not a bad one: if I had been able to remain faithful to my plan of pursuing a profession with writing as an activity that was on the margins of this life-experience, sooner or later I would have become a writer anyway, but with something extra. (222-23)

At the time of writing these thoughts, Calvino apparently recognized the value that his scientific training would have for his fiction and his philosophical system. Indeed, his training was not paltry – according to the chronology in *Una pietra sopra*, Calvino “supera quattro esami del primo anno, senza peraltro inserirsi nella dimensione metropolitana e nell’ambiente universitario… In gennaio [del 1943] si trasferisce alla Facoltà di Agraria e Forestale della Regia Università di Firenze, dove sostiene tre esami.” (Calvino XVII-XVIII) The young Italo Calvino had, by this record, completed almost half of his training toward a scientific degree (a

¹N.B. For the duration of this study, unless an English translation of a work has appeared in press, all quotations will remain in their original language. - MR
considerable portion of a typically detailed course of study) despite his ultimate decision to
abandon the pursuit of science in favor of writing.

Perhaps in spite of himself, though, Calvino’s thirst for scientific knowledge did not
disappear – on the contrary, he remained the devoted student of a variety of different fields of
scientific knowledge. As a young man, he and his friends “talked a lot about science, cosmology,
[and] the fundamentals of knowledge: Eddington, Planck, Heisenberg, Einstein.” (Hermit in
Paris 140) Eddington, the foremost researcher of the luminosity of stars; Planck, the father of
quantum mechanics; Heisenberg, whose Uncertainty Principle upended the very foundation of
human knowledge; Einstein, whose discovery of relativity stood and stands as the most
important scientific discovery of the twentieth century – these were not small concepts, and that
Calvino was not only apprised of them but could actively discuss them with other writers and
students is a hallmark of how robust his connection with scientific inquiry had remained. He had
begun, already, to fuse his creative impulses with an understanding of concrete scientific fact, a
tendency that he himself would come to recognize as a defining principle – if not the defining
principle – of his particular brand of fiction. His persistent urge to “know” would propel his
creativity:

But the cosmos does not exist, not even for science, it is only the horizon of a
consciousness that goes beyond the individual, where all chauvinistic and
particularistic ideas of humanity are overcome, and one can perhaps attain a non-
anthropomorphic perspective. I have never indulged in cosmic euphoria or
contemplation in this ‘ascent’. More a sense of responsibility toward the universe.
We are part of a chain that starts at sub-atomic or pre-galactic level: giving our
actions and thoughts the continuity with what came before us and what will come
after is something I believe in. And I would want this to be something that could
be gleaned from that collection of fragments that is my oeuvre. (Hermit in Paris
187)

One of Calvino’s most salient influences in merging the logical devices of mathematics
and science with the structures of fiction was the experimental French novelist and poet
Raymond Queneau. We can once again return to the previously-cited chronology in *Una pietra sopra* for details on Calvino’s exposure to Queneau:

[Calvino] finisce di tradurre *I fiori blu* di Raymond Queneau. Alla poliedrica attività del bizzarro scrittore francese rinviano vari aspetti del Calvino maturo: il gusto della comicità estrosa e paradossale (che non sempre s’identifica con il *divertissement*), l’interesse per la scienza e per il gioco combinatorio, un’idea artigianale della letteratura in cui convivono sperimentalismo e classicità. (Calvino XXXIII-XXXIV)

Later, in an interview for *L’Approdo Letterario* in 1968, Calvino discussed Queneau’s historical significance with respect to the innovations he engendered through his own work and that of *Oulipo*, the experimental literary movement Queneau co-founded in Paris.

[Raymond] Queneau is a writer whose hobby is mathematics, and he has more friends among mathematicians than among men of letters… He stresses the place that mathematical thought, through the increasing ‘mathemticization’ of the human sciences, is now acquiring in humanistic culture, and therefore in literature as well. (*Uses of Literature* 30)

Calvino’s intimate exposure to Queneau, not only as a reader but as his translator, served as validation, perhaps, for his own literary-scientific tendencies, and further functioned as a model for what would come to be Calvino’s call for an open and truly interdisciplinary approach to human knowledge.

This distinctive, creative impulse to bridge disciplinary gaps and unify all forms of human knowledge under the banner of fictive exercise is a tendency that Calvino depicted in a number of ways. Near the end of his life, in a lecture intended for presentation at Harvard University, he wrote: “My work as a writer has from the beginning aimed at tracing the lightning flashes of the mental circuits that capture and link points distant from each other in space and time.” (*Six Memos* 48) Like the neural network of the primate brain – wholly similar to the brain of the modern human – so must the map of human knowledge be represented, with connections made apparent between concepts that, while seemingly unrelated on the surface, actually serve to
bring forth new and unexpected meaning on a macroscopic level. This incarnation of an overhead view of societal intelligence, nurtured through exposure to both scientific and humanistic disciplines, unveiled itself to Calvino during a 1959 trip to the United States. As a guest lecturer at a number of Ivy League schools, Calvino toured several scientifically significant facilities in the U.S, and spoke highly of American scientists’ role in their own society.

…I have formed the idea that scientists are the only group which can lead to something new in America, because many of them possess alongside what is predictably the most advanced technical expertise a highly sophisticated knowledge of the humanities, and above all they are the only intellectuals with any power, and with any say… (Hermit in Paris 103)

We might propose, then, that the qualities for which Calvino revered these cultured and erudite researchers are the same for which we now hold Calvino himself in high regard – technical expertise, a varied and deep education, and the agency to work freely based on one’s own methodological philosophy. These scientists mirror, in a way, the Calvino of Cosmicomics and T zero, both monumental works which will be discussed in great depth later in this study.

The ideal of a unified conception of human knowledge was not a new idea. Literary scholar Guy Raffa connects Calvino to Italy’s medieval gold-standard, Dante Alighieri, by way of their shared “desire to provide a unified image of knowledge and culture.” (Raffa 388) He posits that

Italo Calvino identifies the common attitude toward discovery and invention in science, literature and politics as the key to forging a unified culture… In Dante’s day there existed a total view of knowledge, exemplified by the summas and encyclopedias of the preceding centuries and conveniently grounded in the liberal arts curriculum of the trivium and the quadrivium. Against the compartmentalization of philosophers and theologians, moreover, Dante saw in poetry the possibility for bringing together disparate strands of knowledge and forging new configurations. (ibid. 388)

Calvino, then, has joined a long line of thinkers that includes Thomas Aquinas, Dante and Galileo, as well as the more contemporary C.P. Snow, who sought a holistic representation of the
universe through the fusion of all forms of human knowledge. The way to approach this ideal, according to both Raffa and Calvino, is to draw from a number of disciplinary fonts. “Calvino seems to revel in the interplay among hermetic, poetic and scientific discourses,” writes Raffa (ibid. 396). In his estimation, Calvino “seeks to enrich his literary imagination by drawing on scientific and mathematical discourses.” (ibid. 398)

One matter of importance that we have not yet touched upon is the methodology behind such an idealist aspiration – how can a writer draw from the deep wells of both science and fiction in order to bring together the best elements of both? We can return to an earlier interview with Calvino in order to hear his own perspective:

In certain situations it is literature that can work indirectly as a spring to propel the scientist along, providing an example of imaginative courage in taking a hypothesis to its ultimate consequences, and so on. Similarly, in other situations it can work the other way around. At the moment the language of mathematics, of formal logic, can save the writer from the disrepair that words and images have fallen into as a result of being misused. Even so, the writer should not think that he has found anything valid absolutely. Here, too, the example of science can be of use to him, and teach him the patient modesty of considering each and every result as being part of a possibly infinite series of approximations. (Uses of Literature 37-38)

Here, the author reminds us that language is the locus of the exchange between disciplines – with one being more formal and the other more flexible, a writer should simply choose the best to represent the concept or image he/she currently wishes to bring into being. When the language of pure fiction fails, the rigorous, logical qualities of scientific and mathematical language can actually serve to rejuvenate the spirit of a text, alternately loaning it authority and modesty. Both languages can be used judiciously and in balance to achieve a particular goal.

Indeed, the language chosen for a particular work can predetermine its readership and potentially expand its influence to uncommon spheres; Calvino himself notes this in “Whom Do We Write For?” by stating that “a literary situation begins to get interesting when one writes
novels for people who are not readers of novels alone, and when one writes literature while thinking of a shelf of books that are not all literary.” (Uses of Literature 82) Later, in a lecture entitled “Lightness,” Calvino restates even more eloquently this philosophy of uniting the disparate.

Whenever humanity seems condemned to heaviness, I think I should fly like Perseus into a different space. I don’t mean escaping into dreams or into the irrational. I mean that I have to change my approach, look at the world from a different perspective, with a different logic and with fresh methods of cognition and verification… But if literature is not enough to assure me that I am not just chasing dreams, I look to science to nourish my visions in which all heaviness disappears.” (Six Memos 7-8)

A tether to the real world and a balm for the sometimes unrelenting heaviness of the imagination, scientific language, for Calvino – and for Borges, as we will soon see – can verify the rational and contextualize the irrational.

Several of Calvino’s final lectures, taken along with “Lightness” from Six Memos for the Next Millennium, echo this sentiment, framing it as a defining thought during what would come to be the last days of his life. In “Visibility,” Calvino decodes the spirit behind the structure of his Cosmicomics:

In Cosmicomics (1965) the procedure was a little different, since the point of departure was a statement taken from the language of science; the independent play of the visual images had to arise from this conceptual statement. My aim was to show that writing using images typical of myth can grow from any soil, even from language farthest away from any visual image, as the language of science is today. Even in reading the most technical scientific book or the most abstract book of philosophy, one can come across a phrase that unexpectedly stimulates the visual imagination.” (Six Memos 89-90)

Rather than simply overlay scientific themes onto the traditional framework of literary fiction, Calvino instead chose to start from scientific seed and cultivate a distinct breed of “science fiction” that would be rooted in logic and experimental observation. In this set of lectures, which essentially serve as a tally of Calvino’s values at the end of his life, his wish for an imaginative
and scientifically-informed literary language is well-stated. In “Multiplicity,” the last of the lectures, he leaves us with a final exhortation: “Among the values I would like passed on to the next millennium, there is this above all: a literature that has absorbed the taste for mental orderliness and exactitude, the intelligence of poetry, but at the same time that of science and philosophy.” (ibid. 118)

It is one thing to exhort, of course, and another to put such a personal philosophy into active use. Calvino appears to have anticipated this criticism and, at a number of times, delved into more technical discussions of his craft. *Six Memos for the Next Millennium* – a posthumously published work that stands as the sum total of his literary philosophy – provides us with a vividly scientific metaphor that stresses the plurality found in good writing. “Even if the overall design [of a book] has been minutely planned, what matters not is the enclosure of the work within a harmonious figure, but the centrifugal force produced by it – a plurality of languages as a guarantee of truth that is not merely partial.” (Calvino 116) The centrifuge – an essential piece of equipment in even the simplest of scientific laboratories – is used to separate materials from an object or substance according to their relative densities. It is fitting that Calvino reinforced the unimportance of a “harmonious figure” when, in fact, what constitutes his ideal of literature can essentially be described as what has been spun *out* of the substance, and not the original substance itself. Calvino’s scientific and interdisciplinary bent places informational objects in a literary centrifuge and extracts vocabulary, imagery, style, tone, and spirit, readying such elements for recombination according to his aesthetic and philosophical judgment.

But what can power a “literary centrifuge”? There must be a catalyst or sustaining effort that defines its operation and connects it to reality; here, again, our neurotically forward-thinking
Calvino seems to have anticipated such criticism. Rigor, he explains, can act as a control to literary experimentation.

…I do believe in a type of education by means of literature; a type of education that can yield results only if it is difficult and indirect, if it implies the arduous attainment of literary stringency. Any result attained by literature, as long as it is stringent and rigorous, may be considered firm ground for all practical activities for anyone who aspires to the construction of a mental order solid and complex enough to contain the disorder of the world within itself; for anyone aiming to establish a method subtle and flexible enough to be the same thing as an absence of any method, whatever. (Uses of Literature 99)

By outlining what basically amounts to a literary-scientific methodology, Calvino expresses an approach to fiction-writing that harnesses rigorous structuring to give the illusion of a lack of structure – in other words, a fiction that dissolves all traces of its own methodology. If the artifice behind fiction can be masked or erased, then little is left to define it as “fiction” per se. In fact, as Calvino justifies in “La sfida al labirinto,” fiction and science are both achieved by way of the same methodology, and thus are already intrinsically fused by virtue of their common genesis.

Già l’atteggiamento scientifico e quello poetico coincidono: entrambi sono atteggiamenti insieme di ricerca e di progettazione, di scoperta e di invenzione. L’atteggiamento politico anche (in senso lato: cioè del far storia, culturale e civile). La via per rendere una la cultura del nostro tempo, altrimenti così divergente nei suoi discorsi specifici, è proprio in questo comune atteggiamento. (Una pietra sopra 102)

These two disciplines are so often separated from each other through the perception that one may hold utilitarian value while the other may not, but Calvino resists succumbing to this fragmented approach to knowledge and emphasizes the crucial function of a literature that truly brings together diverse and disparate forms of human intelligence: “Oggi cominciamo a richiedere dalla letteratura qualcosa di più d’una conoscenza dell’epoca o d’una mimesi degli aspetti interni degli oggetti o di quelli interni dell’animo umano. Vogliamo dalla letteratura un’immagine
cosmica…” (ibid. 116) Like his predecessors Galileo and Dante, Calvino sees the “cosmic image” that is an ideal literature’s goal, and he is clear, as well, about why this is a goal worth striving for.

In order to see the value in a system of creative writing that is fully inclusive of scientific disciplines, it is necessary to first see the specific structural connections between these two concepts. There is much more connecting them than there is dividing them; in “Exactitude,” for example, Calvino highlights some of these links.

[The] taste for geometrical composition, of which we could trace a history in world literature starting with Mallarmé, is based on the contrast of order and disorder fundamental to contemporary science. The universe disintegrates into a cloud of heat, it falls inevitably into a vortex of entropy, but within this irreversible process there may be areas of order, portions of the existent that tend toward a form, privileged points in which we seem to discern a design or perspective. (ibid. 69)

By mimicking within a work of fiction the inherent geometrical systems of nature – that is to say, by contrasting elements of disorder and order within its established parameters – a writer can grant the reader access to such so-called “privileged points” that allow a glimpse into the macroscopic structure of a work. This is most certainly not to say that any particular work will be imbued with a distinctive meaning by way of this approach, however; on the contrary, the work will instead continue to faithfully reproduce the essential labor of human experience – the production of provisional meaning in an otherwise neutral and autonomous universe.

In the spirit of this denial of absolute truth, Calvino explains the importance of the “comic” in good writing – his own included – based on comedy’s traditional role of calling into question its own authority.

Gli anni Sessanta sono un’epoca di rinnovamento dell’orizzonte culturale, vista l’inadeguatezza del modo di conoscenza umanistica a comprendere il mondo. Linguistica, antropologia strutturale, semiologia: la frequentazione di questi territori si fa sentire nei miei scritti di questa stagione, anche se non mi abbandona.
Comic language, then, “lies the least” – in Calvino’s terms, this shrugging, winking framework is ideal for combining unlikely bedfellows from widely-separated disciplines and allowing the reader to simply contemplate their presence alongside each other. They resist fusion or resolution, but the light-hearted absurdity of a comical tone serves to remove a measure of investigative pressure on the reader, thereby allowing him/her to contemplate freely without rendering a final decision. If the comic cannot be trusted, there is no expectation that the reader do so – we might guess that the perpetually anxious Calvino no doubt considered this a very generous gift on his part!

Kerstin Pilz, perhaps the foremost researcher of Calvino’s scientific tendencies, weighs in on this potential farrago of disciplines and archetypes, championing an image of Calvino as a literary scientist in an article entitled “Calvino’s (Post)modern Re-evaluation of Cosmogony”: 

Calvino’s brand of cosmology blends different forms of knowledge, from literature to myth, from philosophy to the visual arts, amongst which science is but one form of knowledge… In other words, [Calvino] weave[s] a synchronic narrative of knowledge – inclusive of different genres and cognitive branches – that demonstrates how literature can serve science as an example of a different form of imagination.” (Pilz 199)

This particular form of imagination eschews, or rather de-emphasizes the traditional scientific goal of resolution in favor of pure thought and free contemplation. For Calvino, it seems to be enough to allow oneself to simply gaze, to let the mind attempt an endless array of combinations and arrangements of elements culled from absolutely everywhere – a process that might well elicit a knowing smile from Henri Poincaré, whom we will encounter in a later chapter.
As a purely literary philosophy, thereby shielded from the historically concrete expectations of scientific philosophy, this approach of Calvino’s may seem to be somewhat incomplete. Indeed, there are irresolvable conflicts – both external and internal – but as will be shown later in this study, these same conflicts plague science just as virulently as they do fiction, with a prime difference being that literature has perhaps come closer to accepting this undeniable fact. Pilz is careful not to represent Calvino’s system as perfect or complete, and even remarks on what seems to be Calvino’s continual struggle with resolution: “Yet… whilst in theory Calvino was ready to embrace new epistemological perspectives inclusive of chance and disorder… he did so reluctantly, as expressed in the anguish and disorientation his characters experience.” (ibid. 204) Through Palomar’s ever-increasing anxiety, Kublai Khan’s spiraling confusion and even the befuddling second-person narration of *If on a Winter’s Night a Traveler*..., an astute reader can trace the trajectory of Calvino’s efforts both to hypothesize and to solve. This tension hearkens back to the well-documented dualism of his childhood, in which he craved fiction but was fed mostly science.²

In 1985, just prior to his death, Calvino mused on the difficulty created by the role of random chance in human knowledge.

What tends to emerge from the great novels of the twentieth century is the idea of an *open* encyclopedia, an adjective that certainly contradicts the noun *encyclopedia*, which etymologically implies an attempt to exhaust knowledge of the world by enclosing it in a circle. But today we can no longer think in terms of a totality that is not potential, conjectural and manifold. (*Six Memos* 116)

Almost as if it were the result of all of the experimentation of his past works, this statement carries with it a note of resignation, but also excitement. By accepting that knowledge cannot be encircled – that it cannot be totalized or completed – Calvino also allows himself to engage in

²“I have always greatly admired and loved the rigour of philosophy and science, but always from a bit of a distance.” (*Hermit in Paris* 249)
the pure enjoyment and freedom of unfettered experimentation. He has come to grips, we could be led to think, with the reality of a shared ceiling for both fiction and science – the unknowable.

Before moving on to an analysis of the crossroads of Calvino and one of his greatest influences, Jorge Luis Borges, it would serve our study well to consider the relative importance of what has been discussed so far. Why compare fiction with science? Why bother assembling a mélange of elements from such varied and seemingly unrelated disciplines? In “Whom Do We Write For?” Italo Calvino focuses on the role of awareness in expanding human knowledge;

> The effect that an important book, literary or scientific, can have on the general struggle in progress is to raise the struggle to a higher level of awareness, to add to its instruments of knowledge, of foresight, of imagination, of concentration, etc… the decisive element in judging a work with reference to the struggle is the level it is on, the step ahead it enables awareness to take. (Calvino 87)

Each aspect, element or trope taken from an isolated field of study and added to the sum total of human knowledge is precious, inasmuch as it functions as a tool to pry open, examine and manipulate reality and its laws. Regardless of the discipline within which it was conceived, each new work pushes humanity forward. The task of the writer, then, is to combine, distill and innovate in order to nurture this ongoing creative and imaginative process.

**Calvino’s Awareness of Borges**

Calvino was in no way shy about the magnitude of Borges’ influence on his own literary philosophy. Citations and examples from Borges abound in Calvino’s non-fiction production, ranging from passing mentions in interviews to full, essayistic discussions in his lectures. It will be useful to highlight a number of these in order to better define precisely what aspects of Borges’ model may have been filtered into Calvino’s own methodology.
*Hermit in Paris*, a posthumous collection of Calvino’s autobiographical writing, details, among other things, his 1959 journey to the United States, a country that long captivated Calvino’s fascination. During this trip he had occasion to visit a number of important monuments, historical sites and scientific facilities. One mention of Jorge Luis Borges appears in a section entitled “The Monument,” which recounts a stint in San Francisco and gives the reader a rather delightful glimpse of what “Borges” had come to mean to Calvino at that particular time in his life.

Going through a park near the Golden Gate, suddenly you find yourself facing a huge neoclassical construction, all surrounded with columns, reflected in a lake, a thing of immense proportions; it is in ruins, with plants growing inside it and this huge ruin is all made of papier mâché and rounded off with great care. It produces a surreal, nightmarish effect, not even Borges could have dreamt up anything like this. (Calvino 78)

The writing style of Borges, here, is analogous in meaning to “surreal” and “nightmarish,” a set of terms that have often been used to describe the fictions of Franz Kafka as well. By 1959, the majority of Borges’ most well-known and notorious works of short fiction had been published; because of this, we can be reasonably certain that Calvino’s opinion was informed by at least a cursory exposure to works such as “The Aleph,” “The Library of Babel” and any number of other short stories by Borges that suggest the horror and immensity of the infinite.

Later in *Hermit in Paris* – and further along on Calvino’s American itinerary – the editor offers readers an essay entitled “My City is New York,” which is a loving description of the frantic and exceptional city that entranced Calvino during his sojourn. He eventually segues into a brief discussion of American literature, and during this *excursus* we find another mention of Borges, this time aside other esteemed company.

I am a writer of short stories first and foremost more than a novelist, so one area of reading which has certainly influenced me, right from childhood, if you like, and not just in an American context but in absolute terms, I would say is Edgar Allan Poe, since he is a writer who knows how to do everything, in terms of the
short story. Within its confines he is an author of limitless possibilities; and also because he seems to be a mythical figure, a hero of literature, a cultural hero, founder of all the narrative genres that would be developed after him. For this reason one can trace lines which link Poe with, for instance, Borges or Kafka: you could trace extraordinary links like this that never end. (ibid. 236)

Within a constellation of exceptional writers, Calvino has situated Borges as an equal to the likes of Poe and Kafka. In addition to further demonstrating the high opinion that Calvino clearly held of Borges, the link with Kafka also reinforces his earlier comments about the “nightmarish” structure and often exponentially vertiginous implications of Borges’ prose. The connection drawn with Poe, as well, might be based on both writers’ shared ability to seamlessly bring together the real world and the imaginary, or the concrete and the dreamlike.

An extension of this last concept can be found in another essay by Calvino, this time taken from *The Uses of Literature*, a 1987 English-language collection of his major philosophical and didactic writings and interviews. In an article titled simply “Philosophy and Literature,” Calvino describes Borges’ as “a literature that breathes the air of philosophy and science but at the same time keeps its distance, while with a gentle puff it blows away both theoretical abstractions and the apparent concreteness of reality.” (Calvino 46) As before, he depicts Borges’ writing as possessing an inherent airiness, able at once to approach the solidity of scientific language and yet disperse it in a single fiat. The literary connections continue here, as well;

Queneau, Borges, Arno Schmidt – all have different relations with different philosophies, and use these to nourish vastly diverse visionary and linguistic worlds. Common to all of them is the habit of holding their cards close to the chest. Their philosophical sorties appear only through allusions to the great texts, metaphysical geometry, and erudition. From one moment to the next we expect the secret filigree of the universe to be made manifest: an expectation that is always disappointed, as is only right. (ibid. 47-48)

Again we encounter a semblance of coherent rigidity, and again an ultimate dissolution, as if reality itself were a fabric that could be shredded and unraveled at will. The perennial
disappointment mentioned here gains further significance if we add to the discussion more modern events such as the perplexing hunt for the elusive Higgs boson, or our almost-hopeless quest to “see” dark matter. This “secret filigree of the universe” is indeed being groped for in both the literary and scientific domains, and Calvino seems to have carried no doubt as to the importance of Borges’ writing toward this end.

Una pietra sopra, an indispensible work that we have cited previously, provides additional discussions of Borges’ style that serve to further define the aspects of it that were most important to Calvino. “La sfida al labirinto” offers a description of Borges’ most famous literary subject as “il labirinto delle immagini culturali di una cosmogonia più labirintica ancora,” a mise en abîme in which the structures of human society cannot help but mimic the structures of a much larger – or infinitely larger – universe. Careful not to imbue this image with supernatural qualities, however, Calvino goes on to state that Borges “cerca di comporre una immagine dell’universo non mistica anche se desunta da teologi e visionari.” (Calvino 115)

A relatively obvious question that has not been addressed thus far confronts what may amount to the most direct influence possible between two authors – a face-to-face meeting and interaction. The “Cronologia” in Una pietra sopra (a work that was curated by Calvino himself) describes two possible moments where he and Borges could have, but ultimately did not, cross paths: “[Calvino] compie in aprile [del 1984] un breve viaggio in Argentina. In settembre è a Siviglia, dove è stato invitato insieme con Borges a un convegno sulla letteratura fantastica.” (ibid. XL) Aside from these recounted situations, there is unfortunately precious little information regarding any other possible encounters between these two men.

Much as Calvino seems to have suggested in his earlier descriptions of Borges’ fiction – specifically when employing the adjectives “surreal” and “nightmarish” – the litany of Borgesian
qualities espoused in Calvino’s final work re-states and elaborates on the true foundations of Calvino’s awe for Borges, which seems to hinge largely upon what may have previously perturbed him about the Argentine. He identifies Borges as a master of the “quick” form, and as an enduring symbol of the open-ended literary processes that are also found in Queneau, Calvino’s other inspirational archon.

The last great invention of a new literary genre in our time was achieved by a master of the short form, Jorge Luis Borges. It was the invention of himself as narrator, that ‘Columbus’ egg,’ which enabled him to get over the mental block that until nearly forty years of age prevented him from moving beyond essays to fiction… What I particularly wish to stress is how Borges achieves his approaches to the infinite without the least congestion, in the most crystalline, sober, and airy style. In the same way, his synthetic, sidelong manner of narration brings with it a language that is everywhere concrete and precise, whose inventiveness is shown in the variety of rhythms, the syntactic movements, the unfailingly surprising and unexpected adjectives. Borges has created a literature raised to the second power and, at the same time, a literature that is like the extraction of the square root of itself. It is a ‘potential literature’… (Six Memos 50-51)

“Potential literature,” at first blush, could be understood as an empty phrase, an ironic and clever piece of jargon with no real definition; that is, until one encounters its apotheosis in Borges. As Calvino explains, Borges’ narrative and structural approach seems to be in conflict with the rules of any corresponding genre – it elbows its way into a room crowded with formulaic signs and symbols and it modifies, denies, subverts – “e stranges,” as Viktor Shklovsky might have put it³ – reimagining a genre from the ground up and retrofitting it with new adornments. The function of surprise and disappointment in Borges’ oeuvre cannot be understated, as this is precisely where his fresh “potentiality” is to be found.

Other essays in Six Memos for the Next Millennium provide additional insights; “Exactitude,” for example, describes a trajectory of narrative that we will refer to as “entropic,” inasmuch as it mimics the natural thermodynamic process of entropy (a concept to be discussed

in great depth in the next chapter). For now, Calvino’s presentation of this image will suffice in defining it, as well as in illustrating the proposed connection to Borges.

This taste for geometrical composition, of which we could trace a history in world literature starting with Mallarmé, is based on the contrast of order and disorder fundamental to contemporary science. The universe disintegrates into a cloud of heat, it falls inevitably into a vortex of entropy, but within this irresistible process there may be areas of order, portions of the existent that tend toward a form, privileged points in which we seem to discern a design or perspective. A work of literature is one of these minimal portions in which the existent crystallizes into a form, acquires a meaning – not fixed, not definitive, not hardened into a mineral immobility, but alive as an organism. (ibid. 70)

According to Calvino, the definition of apparent meaning as the representation of a single, temporary instant during a larger-scale process of universal disintegration is a hallmark of “a whole constellation of poets and writers,” among them “Jorge Luis Borges of Argentina.” (ibid. 70) Whether these writers were cognizant of this interpretation is, of course, irrelevant – Calvino’s reading may be fittingly seen as a “potential” interpretation of what, in turn, has been included within the broader category of “potential literature.”

In what is alleged to have been the last essay written by Calvino before his death, he names Jorge Luis Borges as the ideal model for the writer of the next millennium.

If I had to say which fiction writer has perfectly achieved Valéry’s aesthetic ideal of exactitude in imagination and in language, creating works that match the rigorous geometry of the crystal and the abstraction of deductive reasoning, I would without hesitation say Jorge Luis Borges. The reasons for my fondness for Borges do not end here, but I will mention only the main ones. I love his work because every one of his pieces contains a model of the universe or of an attribute of the universe (infinity, the innumerable, time eternal or present or cyclic); because they are texts contained in only a few pages, with an exemplary economy of expression; because his stories often take the outer form of some genre from popular literature, a form proved by long usage, which creates almost mythical structures. (ibid. 118-119)

In short, Calvino finds Borges’ writing to be the embodiment of many of the ideals he has outlined in this short collection of essays: lightness and universality; multiplicity and multiplication; economy and precision of expression. It would be difficult for any serious scholar
of Borges’ work to disagree with Calvino’s glowing appraisal, although it remains for this current study to prove the unbroken line between these two authors – a line that moves ever forward, thermodynamically, beyond the ends of both of their lives.

**Borges’ Scientific Understanding**

Fortunately for our study, the path to understanding Borges’ scientific background is well tread. Several scholars have produced expansive works that delve in great detail into the mathematical and practical implications of the images found in Borges’ fiction, with one of the most notable among these scholars being William Goldbloom Bloch, who has penned an exceptional study entitled *The Unimaginable Mathematics of Borges’ Library of Babel*. A massively dense work of comparative literary scholarship, this book shines light into the most remote corners of Borges’ infamous “Library” and decodes its physical dimensions and contents from every possible angle. There are no unanswered questions that remain about the Library following the publishing of this work, and our present study is greatly indebted to Bloch’s labor.

Bloch’s interest in Borges is not purely mathematical – better said, Bloch seems to be primarily interested in Borges’ mathematical exercises as a means of demonstrating the creative side of scientific inquiry. He tells us early on in his book that:

> Mathematics can be creative, whimsical, and revelatory all at once. More to the point, as embodied in the different meanings of the word ‘analysis,’ it is simultaneously a process and an intellectual structure. Borges, a great imbiber of mathematics, seems to have understood this idea and instantiated it in many of his stories… His imagination works in, through, out, about, and all around logical structures. (Bloch XII)

In exact symmetry with Calvino’s educational and literary ideal, Bloch feels that Borges also fuses a robust fictive imagination with scientific rigor in a symbiotic union of creativity and logic. Borges’ universes exist according to well-defined scientific parameters, and even when
these parameters are transgressed Borges is adept at disguising this guile as an “unknown,” or an “unknowable” – a point that Bloch goes on to prove at several junctures in his analysis.

Bloch delves more deeply than purely textual analysis, though – he even goes as far as to travel to Argentina to scour Borges’ archives for evidence of his scientific education.

While visiting the National Library of Argentina, I had the great pleasure of perusing the math and science books Borges donated to the collection… I discovered that Borges marked the back end leaves of his volumes with his name, the year of acquisition, and the page numbers –coupled with a succinct phrase – of passages that especially interested him. (ibid. 143)

Thanks to this rather obsessive tendency toward note-keeping, Borges fortunately left a trail for literary scholars to follow in their pursuit of historical information related to his study habits and reading preferences.

Bloch’s research leads to several striking discoveries, the first of which delivers an insight that will become more meaningful in the next chapter of this study.

There are at least two candidates from Borges’ personal library to which it is tempting to assign influential status in the development of his mathematical thought. The first is Henri Poincaré’s 1908 book Science et Méthode. Borges’ end leaf notations, dated 1939, indicate an interest in Lesage’s discredited theory of gravitation and, more tellingly, in geometry and Cantor. (Bloch 144-145)

Georg Cantor and Henri Poincaré, as will be demonstrated, are the representatives of mathematical philosophies and ideas that came to form the bases of a number of Borges’ short fictions. The most notorious of these concepts, Cantor’s theory of transfinite sets, would come to be mentioned by name in several of Borges’ essays and stories, and clearly served as the unspoken inspiration for many others.

Bloch goes on to expand his study of Borges’ personal library –

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The other book from Borges’ library, philosophically opposed to Poincaré’s, is Bertrand Russell’s *Principles of Mathematics*. The book was originally published in 1903, and Borges’ copy is a 1938 printing… The easiest opening of this volume, and the first page singled out by Borges, concerns a resolution of Parmenides’ paradox. The next page pleasantly segues into a discussion of Zeno’s paradox of Achilles and the tortoise. (Bloch 145-146)

Parmenides’ paradox – briefly: that everything always exists and that nothing ever changes – and the paradox of his student Zeno – that space is infinitely divisible – appear in various forms in Borges’ fictions and essays, often by name and most explicitly in a 1929 work entitled “The Perpetual Race of Achilles and the Tortoise.” Bloch acknowledges that these citations serve as signposts to a number of recurring symbols, themes and tropes in Borges’ imagined universes, and that they illustrate the breadth and scope of Borges’ exquisite scientific and philosophical education.

Another major scholar of the scientific Borges, Floyd Merrell, will provide additional counsel throughout our study; for now it will be necessary to dwell on a few of his statements regarding Borges’ successful enterprise in fusing the scientific and the literary. Early on in his 1991 work *Unthinking Thinking: Jorge Luis Borges, Mathematics and the New Physics*, Merrell focuses explicitly on Borges’ fictive exercises and just how much his methodology mimics that of the scientists.

The impossibility of penetrating the divine plan of the universe… does not discourage Borges from inventing limited human constructs, always remaining mindful that they can be no more than provisional… Mathematics, in Borges’ tales, is accordingly fictive… An affinity between literary fiction-making and the use of mathematical fictions might possibly be validated, then, since both are based on a fictional standard. (Merrell 20-21)

The invocation of this cross-disciplinary affinity justifies our own premise, and also acts as a hub in which Calvino and Borges’ literary ideals can be shown to coexist. In addition to allowing us the justification to compare style and motive across disciplines, Merrell’s insight also lays bare
the provisional basis that is the foundation of both literature and science – an idea that will be
cast in deep relief during our discussion of Kurt Gödel in the next chapter.

Interestingly, Merrell notes an even more specific distinction within science itself –
namely the conceptual gap between mathematics and physics – with the objective of further
developing his concept of the fictional bases of the “hard” sciences.

Mathematics is not, ipso facto, about ‘reality’. It is, however, appropriated by the
physicist to describe an intangible, and for practical purposes, incomprehensible
world. But this description can be no more than a…fiction. When one abstract
formulation no longer effectively accounts for the ‘facts’, it is to be conveniently
discarded and another embraced. So all scientific frameworks, it is becoming
increasingly apparent, are merely temporary; and they are conventional. Borges
creates alternative worlds in his metaphysical fictions. But scientists and
mathematicians have always exercised the same prerogative. (ibid. 23)

There is no difference, then, between the “alternative worlds” created in literature and those
theorized in science – both are conventions, or artificial supports that function to temporarily
prop up an idea or philosophy. We create the image of a world or a universe – Tlön, for example,
in the case of Borges, or the adjacent and concurrent multiverses of Hugh Everett III in the case
of physics – in order to establish a functional basis for postulation. Without these imaginary
pylons we cannot visualize, and therefore we cannot theorize. The fictive act, then, is crucial to
the basic operation of creative thought regardless of its final goal or the particular
methodological process employed.

Merrell continues his analysis with an impressive logical insight that further strengthens
our own study:

Borges repeatedly erects elaborate mental constructs, but he knows the fiction
must soon end, that his relating a particular or a collection of particulars to the
universal is ephemeral. So he demolishes his edifice, the fiction comes to a close,
and we are left in our own perishable world… Like Borges’ fictions, all world
pictures will eventually be demolished. If every scientific theory except those
accepted today is considered to a greater or lesser degree falsified, then there is
virtually an infinitely greater probability that today’s theories are false rather than
true. (ibid. 30)
The scientific disciplines continually discard and renew the provisional edifices that they construct in order to shed those elements that are non-functional, as well as to polish and amend theories to the best of the current base of knowledge. Similarly, writers of fiction – with Borges among them – create temporary universes that are to be demolished after they have served their purpose in provoking thought and sparking, in turn, further creativity. “Absolute Truth” remains, for both disciplines, a necessarily unattainable goal. A work of fiction cannot live forever – in fact, it cannot live at all. It can only potentially exist: a distinction that functions identically for scientific theories and brings our own study closer to linking the flights of potentiality (by way of Queneau and Oulipo) to be found in Italo Calvino’s philosophy and literary production with the ephemeral, superposed universes generated by modern physics and nurtured by Jorge Luis Borges.

As a South-American writer, Borges has unsurprisingly received a preponderance of attention from scholars based all over the continent of his birth. Several have focused on the scientific aspects of Borges’ body of writing, and among these scholars stands out Guillermo Martinez, the author of a 2003 series of lectures presented at the Museo de Arte Latinoamericano de Buenos Aires entitled Borges y la matemática. A much less detailed overview than those provided by Bloch and Merrell and intended, apparently, for those with a more passive or lay interest in the scientific aspects of Jorge Luis Borges’ writing, this collection nevertheless adds several exhibits to the mound of proof for Borges’ scientific bent.

Podríamos encontrar o forzar al texto a decir cosas que el texto no dice, ni tiene ninguna intención de decir. Un error di erudición. Por otro lado, si desconocemos en absoluto los elementos de matemática que están presentes reiteradamente en la obra de Borges, podemos quedar por debajo del texto. (Martinez 8)
It can be easy to misread Borges, specifically because of the potentiality inherent in his writing style, but Martínez argues that in certain cases we can be very sure of our judgment in reading Borges mathematically. He goes on to specify that

…está claro que Borges sabe por lo menos los temas que están contenidos en el libro que él prologa, *Matemáticas e imaginación* [by Kasner and Newman], y que son bastantes… Se tratan allí las paradojas lógicas, la cuestión de las diversas clases de infinito, algunos problemas básicos de topología, la teoría de las probabilidades. (ibid. 10-11)

While this is not exactly a groundbreaking discovery on Martínez’ part – as even a casual reading of Borges would introduce the reader to these concepts – this statement serves to reinforce what Bloch and Merrell have already demonstrated and proven with regard to Borges’ fixation on the mathematical, the infinite, and the probabilistic. In apparent agreement with Merrell, Martínez delineates the shared ground between Borges’ fictive process and the traditionally accepted scientific method:

*Borges es un escritor que procede desde una idea: <<en el principio era la idea>>, y concibe sus ficciones como encarnaciones o avatares de una concepción abstracta. Hay también fragmentos de argumentación lógica en muchos de los relatos. Este tipo de matriz ensayística…es, indudablemente, uno de los elementos que marcan cierta similitud con el pensamiento científico. (ibid. 41)

Borges’ structural signature in fiction-making can therefore be compared with great success to the matrices required for forming and executing experimental scientific hypotheses. The presence of logical argumentation (even when involving fictional precepts) allows Borges to proceed along the same trajectory as one would within a physical experiment or mathematical proof, and, as we have seen stated a number of times already, permits him to obtain end result that is as inevitably devoid of objective truth as anything that scientific inquiry can produce.

Before turning to Borges’ own words on this topic, we must include the work of another literary scholar who authored a 2007 article entitled “Borges en el territorio de la ciencia:
escrituras y lecturas” – Guillermo Boido, a professor of physics and astronomy and an expert on
the writing of both Calvino and Borges. In this essay, Boido characterizes Calvino and Borges as
authors who work astride “dimensiónes ficcionales de las ciencias formales y naturales”; this
notion quite accurately categorizes Calvino’s entire fictional output as “una tarea seguramente
transdisciplinaria.” (del Toro 59) This is equally true, according to Boido, for both authors. We
might imagine, then, that if Calvino’s ideal literature were to function as a map of the universe,
then Borges’ literary ideal may be depicted as a library that contains the universe within itself.
Boido’s words reflect the consensus that has been seen so far among many literary-scientific
scholars, and he goes on to add more evidence to the case being made of Borges-as-scientist by
virtue of the Argentine author’s education and interests.

El joven Borges fue contemporáneo de algunas de las revoluciones científicas
formales y naturales: la revisión de los fundamentos de la lógica y la matemática,
la teoría de la relatividad, la física cuántica y el desarrollo de la genética moderna
datan del primer tercio del siglo. Célebres científicos, como Bertrand Russell,
Albert Einstein o Julian Huxley, escribían por entonces o poco después libros de
alta divulgación para poner al alcance del profano las nuevas ideas científicas en
circulación. Sabemos incluso los títulos de algunos de ellos que Borges,
insaciable lector de la cultura de su época, sin distinción de fronteras, leyó en
distintos momentos de su vida… En múltiples escritos, Borges incursiona por las
autoreferencias y las regresiones infinitas de la lógica, los números transfinitos,
las series infinitas, la infinita divisibilidad del espacio y el tiempo, la
irreversibilidad termodinámica, las simetrías, los universos paralelos, la
cosmología, la memoria o la universalidad del azar, temas que, de un modo u otro,
son patrimonio de la investigación científica actual. (ibid. 47-48)

With a justified lack of brevity, Boido enumerates the most important mathematical and
astrophysical concepts of which Borges showed at least a measure of awareness. We must
assume that Borges attained this knowledge through either chronological proximity to the
appearances of these concepts in the intellectual zeitgeist, or through his own varied and esoteric
tastes. In addition to listing what scientific concepts Borges knew about – which ranged from
transfinite numbers to thermodynamics – Boido also echoes Martinez and Merrell in
emphasizing that the language shared by Borges’ literary output hews closely to that of typical scientific methodology.

Borges had a penchant for resisting the interpretations that scholars generated about his fiction; at times, he would wryly admit that the astonishing connections and symbols that literary critics found in his works were in no way intentional, and that he had no awareness of having woven such tropes and themes into his short stories. On matters of scientific knowledge, however, we are fortunate to have access to a considerable store of undeniably explicit proof in Borges’ non-fiction works. Here, we can allow Borges to speak for himself.

**Borges’ Scientific Formation**

In order to trace the development of Borges’ understanding of scientific topics it would be best for us to move chronologically through a selection of his non-fiction works, beginning with “Verbiage for Poems,” written in 1926. Amid a discussion of poetic language, Borges states the following:

I am insisting on the inventive character of any language, and I do so intentionally. Languages construct realities. The various disciplines of the intelligence have engendered worlds of their own and possess an exclusive vocabulary to describe them. The mathematical sciences wield their particular language made of digits and signs, no less subtle than any other. Metaphysics, the natural sciences, the arts, have all considerably increased our general store of words. (Selected Non-Fictions 21-22)

This early position held by Borges seems to have already hinted at a well-formed understanding of the shared foundations of science and literature, with both disciplines functioning as equal contributors to the unified body of human language. In stating that “languages construct realities,” Borges also demonstrates an agreement with those – like Kurt Gödel – who first posited the provisional nature of the sciences and the distance created, through language,

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between that which exists and that which can be described. Despite this quotation’s placement at the early end of Borges’ career, it nonetheless represents an opinion that would not change significantly during the rest of his life.

A year later Borges presented “An Investigation of the Word,” and like many of his early essays it focuses specifically on language, but this time with a direct link to combinatorial mathematics.

Llull – inspired by Jesus, they say – invented the so-called thinking machine, a kind of glorified lottery, though with a different mechanism; Spinoza did not postulate more than eight definitions and seven axioms to level the universe for us. As we can see, neither the latter with his geometric metaphysics nor the former with his alphabet translatable into words, and these into sentences, managed to elude language. Both systems were nourished by it. (ibid. 39)

Raymond Llull and Baruch Spinoza – both icons of metaphysical science – attempted to circumvent language in their approaches to the Absolute, but here Borges notes the primacy of language in what may first appear to be “pure” mathematical exploits. Arithmetical ideas, no matter how simple, cannot be expressed except through a language, and simply switching the code from a spoken language to the shorthand language of logic – or even removing human thought from linguistic exercises entirely – will not succeed in shedding the albatross of language. It is not surprising, given the obstacle that language represents to the work of moving beyond finite human understanding and toward the Absolute, that Borges exhausted so many pages working out his own philosophy on the matter.

1929 would bring one of Borges’ better-known treatises on science: an essay entitled “The Perpetual Race of Achilles and the Tortoise.” It is as much a discussion of Bertrand Russell as a refutation of the postulations of Zeno and Parmenides, and will be analyzed in greater detail in the coming chapters. However, it is valuable to our current discussion in showing Borges’ familiarity with the philosophical icons who appear within its lines: the Greek mathematician
Parmenides and his disciple Zeno; Henri Bergson, a French philosopher who was also cited a number of times by Italo Calvino and whose philosophy focused on the role of intuition and creativity in understanding the structures of time and space; and Bertrand Russell, whose *Introduction to Mathematical Philosophy* and *Knowledge of the External World* Borges had avidly read and wryly defined as “unsatisfactory, intense book, inhumanly lucid.” (ibid. 46)

We can unexpectedly watch Borges beginning to flirt with astrophysics in “A Defense of Basilides the False,” wherein he mentions, in passing and with no additional context, “Richter’s discarded theory about the stellar origins of life and its chance dissemination on this planet.” (ibid. 68) Further research would come to show that Borges was referring to an extremely esoteric 1865 theory by Hermann Eberhard Richter which defined the concept of “cozmozoa” – specifically, that the organic life found on Earth might be essentially eternal, and that meteors could have carried such organic life around the cosmos, seeding it onto planets where they inevitably crashed. This is, of course, a terribly fanciful and ambitious hypothesis, given that there was (and is) no physical evidence of its veracity. In Borges, though, this theory simply serves to further demonstrate his far-reaching scientific curiosity and insatiable appetite for arcane knowledge.

By 1936, we can see Borges beginning to include more astrophysical themes in his non-fiction essays, with “The Doctrine of Cycles” being a noteworthy example. On a general level, Borges seems to have written this piece to address Nietszche’s doctrine of “eternal return,” or infinite regress, from *Die Unschuld des Werdens* (1931) and *Also sprach Zarathustra* (1892). By the end of this uncharacteristically lengthy essay, Borges has nevertheless also managed to show off a great deal of scientific knowledge. He discusses the atomic characteristics of hydrogen: “The diameter of a hydrogen atom has been calculated, with some margin of error, to be one
hundred millionth of a centimeter.” (ibid. 115); he mentions “Georg Cantor and his heroic theory of [transfinite] sets” (ibid. 116); and he lays out the tenets of the second law of thermodynamics, even going so far as to address the concept of entropy, thereby demonstrating his awareness of the astrophysical nomenclature for what, at the time, was a very advanced and difficult topic.

The first law of thermodynamics declares that the energy of the universe is constant; the second, that this energy tends toward isolation and disorder, though its total quantity does not decrease. This gradual disintegration of the forces that make up the universe is entropy… The second law of thermodynamics declares that some energetic processes are irreversible. Heat and light are no more than forms of energy. It suffices to project a light onto a black surface to convert it to heat. Heat, however, will never return to the form of light. (ibid. 121-122)

Spring-boarding from this last thought, Borges goes on to detail the expected fate of the universe according to the processes of thermodynamics: an eventual entropic “heat-death.”

Once maximum entropy is reached, once different temperatures have been equalized, once any action of one body on another has been neutralized (or compensated for), the world will be a random assemblage of atoms. In the deep center of the stars, this difficult, mortal equilibrium has been achieved. By dint of constant interchange, the whole universe will reach it, and will be warm and dead. Light is gradually lost in the form of heat; the universe, minute by minute, is becoming invisible. It grows more inconstant, as well. At some point, it will no longer be anything but heat: an equilibrium of immobile, evenly distributed heat. Then it will have died. (ibid. 122)

As desperately hopeless as it is fascinating, this concept is presented by Borges in language that is lucid, clear and didactic while still remaining poetic. That he could not only explain entropy but do so artfully is a testament to his talent as well as his exceptional intelligence, and serves to link him even more strongly to Italo Calvino, whose Cosmicomics and T-zero accomplish a similar feat of transdisciplinary creativity.

In the same year as the previous essay, Borges also produced the confidently-titled “A History of Eternity,” which amounts to little more than a restatement of Bertrand Russell’s own
position on infinity – itself standing in direct opposition with Borges’ other beloved concept of transfinite sets.

The Eleatic refutation of movement raises another problem, which can be expressed thus: *It is impossible for fourteen minutes to elapse in eight hundred years of time, because first seven minutes must pass, and before seven, three and a half, and before three and a half, one and three-quarters, and so on infinitely, so that the fourteen minutes will never be completed.* Russell rebuts this argument by affirming the reality and even the triteness of infinite numbers, which, however, by definition occur once and for all, and not as the “final” term of an endless enumerative process. Russell’s non-normal numbers are a fine anticipation of eternity, which also refuses to be defined by the enumeration of its parts. (SNF 124)

Borges’ provides no hint as to whether he stands in philosophical agreement with Russell, but he was, as we have seen, such an avid reader of Russell’s that we can presume him to have drawn from Russell’s prose on a structural and even logical level. In fact, the real importance of this essay seems to actually be its function as an example of a Borges who flits from thinker to thinker, lighting briefly upon arguments and culling elements from often contradictory positions. His is an unbridled creativity in the spirit of Feyerabend and Kuhn (to be discussed in the next chapter), in which the individual parts of a theoretical structure need not be necessarily or entirely coherent – fostering, in a sense, a fiction that sits atop scientific philosophy.

Borges returns to the person of Raymond Llull in 1937, in a dedicated discussion of the 13th century inventor entitled “Raymond Llull’s Thinking Machine.” Llull had infamously created a mechanism that was touted to “think for itself” by generating random combinations of words without any human intervention. While certainly unprecedented, and also potentially able to create a large number of combinations, Borges notes that Llull’s machine did not “think” so much as simply play out a process initiated by a human mind, and was in this respect a failure. (ibid. 154) Following this dismissal, however, Borges softens his criticism with a measure of understanding and respect for Llull’s intentions. “We (who are basically no less naïve than Llull)
would load the machine differently, no doubt with the words Entropy, Time, Electrons, Potential Energy, Fourth Dimension, Relativity, Protons, Einstein.” (ibid. 157) Rife with provocative astrophysical terminology, this short list keys the reader into Borges’ growing familiarity with the then-current scientific paradigm. He continues: “The circumstances and objectives of this machine… no longer interest us, but its guiding principle – the methodological application of chance to the resolution of a problem – still does.” (ibid. 157) The type of machine built by Llull is worthless for mimicking human thought, then, but still holds immense literary value as its random combinations can inspire creativity and challenge rational thought. Just as interesting and germane to the purposes of our study are Calvino’s own thoughts on combinatorial writing, which are rooted in Raymond Queneau’s experimentation on “potential writing” and the subsequent works of the Oulipo writing group. Calvino would, in fact, go on to produce an entire novel by following the whims of random selection – The Castle of Crossed Destinies can be broadly described as the literary treatment of unplanned groupings of tarot cards, each haphazardly arranged according to chance. The implications of Borges’ interest in Llull, then, are far-reaching, especially within the parameters of a comparison with Italo Calvino.

Moving forward to 1939, we find a titillating excerpt in which Borges recounts his first memory of contact with the infinite – an infinite that is present, in one way or another, in the vast majority of his works of fiction. He takes us back to a scene from his childhood in “When Fiction Lives in Fiction”:

I owe my first inkling of the problem of infinity to a large biscuit tin that was a source of vertiginous mystery during my childhood. On one side of this exceptional object was a Japanese scene; I do not recall the children or warriors who configured it, but I do remember that in a corner of the image the same biscuit tin reappeared with the same picture, and in it the same picture again, and so on (at least by implication) infinitely… (ibid. 160)
This “vertiginous” *mise en abyme* sparked a conflagration in the mind of the young Borges. Like a flame placed between two mirrors, the endlessly recurring biscuit tin seemed to arch into eternity, its permanence tempered only by the limitations of human sight and the speed of light.

It is worth reminding ourselves that, at the time of the penning of this memory, Borges was already well-aware of Cantorian set theory and its boggling structure of infinite sets contained within even more infinite sets. The concepts are identical: if the infinite exists, it exists for all things, and for all time. It is not difficult to see why a mind like Borges’ found unlimited fodder in such a concept.

Permutations of infinity would become heavily recurrent in the period following this essay. Again in 1939 with “The Total Library,” Borges encloses further thoughts on Cantor and the infinite as described by French thinker Blaise Pascal\(^6\) within the structure of a hypothetical, absolute library whose volumes would contain absolutely everything in the universe. His description is startlingly clear:

> Everything would be in its blind volumes… Everything: but for every sensible line or accurate fact there would be millions of meaningless cacophonies, verbal farragoes, and babblings. Everything: but all the generations of mankind could pass before the dizzying shelves – shelves that obliterate the day and on which chaos lies – ever reward them with a tolerable page. (ibid. 216)

We can intuit that Borges fully understands the immense operation of combinatorial mathematics involved in a theoretical exercise on the scale of the “The Total Library.” The infinite is not a “number” in the conventional sense so much as it is a totality, or, inversely, an innumerability. Such a concept does not mesh readily with the finite structures of the human mind; our inability to conceive of totality can lead to ideations of horror, fear or anxiety.

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\(^6\)Coupled with another essay entitled “Pascal’s Sphere” (see *Selected Non-Fictions*, pp. 351-353), this piece demonstrates Borges’ familiarity with Blaise Pascal’s strange orientation between religion and science, and his maddening obsession with infinity.
One of the habits of the mind is the invention of horrible imaginings. The mind has invented Hell, it has invented predestination to Hell, it has imagined the Platonic ideas, the chimera, the sphinx, abnormal transfinite numbers (whose parts are no smaller than the whole), masks, mirrors, operas, the teratological Trinity: the Father, the Son and the unresolvable Ghost, articulated into a single organism… (ibid. 216)

In equating Cantor’s transfinite sets with monsters, theological mysteries and even Hell itself, we can be sure that Borges was no stranger to the terror that can be conjured through extended reflection on the implications of an infinite universe.

One of the briefest examples of Borges’ advanced understanding of physics and mathematics can be found in 1940’s “Time and J.W. Dunne.” Borges effectively introduces the reader to the concept of a fourth physical dimension, and quite correctly apprises us of a very common “bad intellectual habit” of “conceiving of time as a fourth dimension of space.” (ibid. 219) The subtlety of this observation is exquisite; Borges is identifying the difference between what is technically known as “Minkowski space” – or, more colloquially, “spacetime,” in which time is defined as a non-Euclidean fourth dimension that acts upon the three better-known physical dimensions – and true, spatial four-dimensionality within Euclidean space. Most likely gleaned from his many readings in physics and geometry, this distinction drawn between such theoretical minutiae is especially impressive when coming from relative layman such as Borges.

More on Borges’ studies of the fourth dimension can be predictably found in an untranslated essay entitled “La cuarta dimensión.” Borges begins by noting, possibly, the first known usage of the term “fourth dimension” by Henry More in 1670, prior to which these two simple words had been “antes no combinadas.” (Textos Recobrados 95) He then moves into an explication of this idea’s development, while listing a number of scientific and mathematical icons along the way: Kant; Fechner; Helmholtz; Riemann; Whitehead; Einstein; Hinton; and Uspenski. (ibid. 95) After this brief preamble, Borges once again flexes his understanding of the
nuanced distinction between Euclidean and non-Euclidean space. In brief, lucid prose he provides a basic introduction to three-dimensional geometry:

Generalmente, los alegatos por una cuarta dimensión derivan de las definiciones preliminares de la geometría euclideana. Ésta procede de manera sintética: empieza por el punto convencional, que se postula sin dimensión de ninguna clase; pasa después a la línea convencional, que se postula como longitud sin anchura; pasa después a la superficie convencional, que se postula como simple extensión, sin profundidad; y arriba así al volumen o cuerpo, que abarca las tres dimensiones. (ibid. 96)

Almost immediately, though, and much in line with what has already been established regarding the provisionality of the foundations of science and language, Borges doubles back to clarify what he has just presented: “Conviene repetir que esa operación está a cargo de símbolos y que no se concibe el momento en que los puntos inextensos empiezan a trazar una línea, o las líneas sin anchura una superficie, o las superficies un cuerpo.” (ibid. 96) The established description of three-dimensional space, then, is a convention that enables us to conceive of its existence, and does not function as a literal description of the actual structure of space and time.

Points, as he explains, do not “engender” lines, nor do lines surfaces, nor do surfaces volume; all things exist in three dimensions, and only in three dimensions. (ibid. 96) Logically, these three dimensions do not engender a fourth; if a fourth dimension (or fifth, or sixth…) exists, it always does and always has. “La superficie, el punto y la línea son ideales geométricos, pero asimismo lo es el volumen y asimismo lo puede ser el hipervolumen, de cuatro dimensiones.” (ibid. 97) Again, Borges astounds with his knowledge of a subject so traditionally foreign to that of literature, along with his ability to distill such knowledge into a simplified and engaging format that is suitable for varied readership.

It is the latter section of “La cuarta dimensión” that is especially germane to our study, particularly in its representation of science as instrumental in feeding the imagination – an
exercise that is crucial to the production of good fiction. Borges cites Charles Hinton, the
“father” of four-dimensional geometry:

No habrá en el Universo material un solo trángulo absolutamente equilátero, pero
lo podemos intuir; no habrá un solo hipercono, pero alguna vez lo intuiremos. Esa
promesa nos da el libro de Hinton, *Una Nueva Era del Pensamiento*, que consta
de una serie de ejercicios con cubos de diversos colores, para educar la
imaginación. (ibid. 97)

We therefore *can* hope to imagine that which does not exist, and such an endeavor is made much
easier when we are given the germ of an idea before we have begun to visualize. Science, in its
process of generating successive hypotheses, can aid in the creative process by stretching the
limits of that to which our minds have access. Borges, as always, says it best: “Rehusar la cuarta
dimensión es limitar el mundo; afirmarla es enriquecerlo.” (ibid. 97)

Borges was known as much for his book reviews and newspaper columns as he was for
his fictions. Several of these reviews, which were intended for a general audience, can assist us
in further delineating the extent of his scientific knowledge, with his 1940 review of Edward
Kasner and James Newman’s *Mathematics and the Imagination* at the forefront. His commentary
on this work illustrates an awareness of scientific debates regarding the fourth dimension,
transfinite numbers, the paradoxes of Zeno, and Euclidean geometry.

Its four hundred pages lucidly record the immediate and accessible charms of
mathematics, those which even a mere man of letters can understand, or imagine
he understands: the endless map of Brouwer, the fourth dimension glimpsed by
More and which Charles Howard Hinton claims to have intuited, the mildly
obscene Moebius strip, the rudiments of the theory of transfinite numbers, the
eight paradoxes of Zeno, the parallel lines of Desargues that intersect in infinity,
the binary notation Leibniz discovered in the diagrams of the *I Ching*, the
beautiful Euclidean demonstration of the stellar infinity of the prime numbers, the
problem of the tower of Hanoi, the equivocal or two-pronged syllogism. (SNF
249)

In a clear effort to emphasize the accessibility of Kasner and Newman’s book to the layman,
Borges also finds a way to wryly editorialize the narrative behind these scientific concepts,
injecting lightness into a genre that can often come across as terribly dry. One can argue that this approach is analogous to that which Calvino would set forth as an educational ideal; by fusing the emotional capacity of creative writing with the theoretical structure of scientific philosophy, Borges prefigured Calvino’s vision for the future transmission of human knowledge.

Borges’ writing on film was not devoid of scientific subject matter, either; in a very short piece entitled “On Dubbing,” he again invokes the horror of infinity in order to outline the consequences of mixing numerous languages with fixed visuals.

The art of combination is not infinite in its possibilities, though those possibilities are apt to be frightening. The Greeks engendered the chimera, a monster with the head of a lion, the head of a dragon, and the head of a goat; the second-century theologians, the Trinity, in which the Father, the Son, and the Holy Ghost are inextricably linked; the Chinese zoologists, the ti-jiang, a bright red, supernatural bird equipped with six feet and six wings but with neither face nor eyes; nineteenth-century geometrists, the hypercube, a four-dimensional figure enclosing an infinite number of cubes and bounded by eight cubes and twenty-four squares. (ibid. 262)

This hypercube, mentioned in an earlier citation by Borges from “La cuarta dimension,” is placed alongside such fearful creations as the chimera and the ti-jiang and represents the potential insanity that four-dimensionality could cause within the rational and limited human mind, which struggles to conceive of it. Going further, Borges also invokes the tesseract7, another approximate representation – along with the hypercube – of a four-dimensional figure in three-dimensional space. Such an object, if it could ever really exist, would be an abomination in its capacity to boggle and short-circuit human understanding. That Borges could weave such an esoteric discussion into a treatise on film dubbing is proof of his unique ability to harmoniously fuse varied forms of knowledge.

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7 “Hinton spent years developing ingenious methods by which the average person and a growing legion of followers, not only professional mathematicians, could ‘see’ four-dimensional objects. Eventually, he perfected cubes that, if one tried enough, could allow one to visualize hypercubes, or cubes in four dimensions. These would eventually be called Hinton’s cubes. Hinton even coined the official name for an unraveled hypercube, a tesseract, which found its way into the English language.” (Kaku, *Hyperspace* 69-70)
We have so far reviewed a great number of non-fiction works by Borges which have dealt with mathematical and scientific themes, often with a particular focus on the implications of the infinite, and just as often in the midst of wholly non-scientific subject matter. A last area for us to explore, then, is Borges’ insertion of such themes into the works of others – specifically in prologues written for Ray Bradbury and Charles Howard Hinton.

Ray Bradbury’s 1950 short-story collection *The Martian Chronicles* – a fictional future-history of the human race’s escape from a benighted Earth and their subsequent exodus to Mars – was translated into Spanish in 1954, and included a prologue by Borges that invoked the memory of Johannes Kepler, a seventeenth-century astrophysicist (the first of his kind, according to Carl Sagan8):

> In the seventeenth century, Kepler wrote a *Somnium Astronomicum* that purports to be a transcription of a book read in a dream, whose pages reveal at great length the appearance and habits of the lunar snakes, which take shelter in deep caves during the heat of the day and venture out at nightfall. (SNF 418)

Three-hundred years before Bradbury, Kepler had engaged in the same exercise of imagining and detailing a strange civilization on a foreign planet. This “astronomical dream” of Kepler – the product of unrestrained creative freedom and intended as a satire of earthly exploits as seen from the moon – was uncharacteristic of the normally meticulous and rational Kepler, and was not published during his lifetime. Its function in Borges’ prologue seems to be that of bridging not only the chronological gulf between the present and the past but also underlining the constancy of certain “big” human questions: Why are we here? Is there life anywhere else? If so, what is it like? Bradbury and Kepler – two minds situated far apart in time and space – appear to have both attempted the same exercise, and Borges, noting this, links them in order to add significance and weight to a fictional work intended for a popular audience. In this way, popular

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fiction is made into a didactic and philosophical exercise, thereby fulfilling the dual functions of delighting and informing the reader.

Years later, Borges would provide a prologue for Charles Hinton’s *Scientific Romances*, a collection of Hinton’s science-fiction works from the late 1800s which were among the first to deal with themes involving upper-dimensionality. Like Borges’ treatment of this theme in “La cuarta dimensión,” here he sets the stage for Hinton’s “What is the Fourth Dimension?” by once again laying bare the provisional and subjective foundations of mathematics.

We tend to forget that the elements of geometry that are learned in elementary school pertain to abstract concepts and correspond to nothing in so-called reality. These concepts are the point, which occupies no space; the line, which, no matter how long, consists of an infinite number of lines, one on top of the other; and volume, made from an infinite number of planes like an infinite deck of cards. (ibid. 509)

Borges goes on to cite a 17th-century innovation: “the hypervolume formed by an infinite number of volumes, and limited by volumes, not by planes.” He also mentions a number of other four-dimensional, geometrical monsters: “hypercubes, hyperprisms, hyperpyramids, hypercones, truncated hypercones, hyperspheres, etc.” (ibid. 509) These structures would, of course, be desperately beyond the preparation of the average reader of fiction, but we might presume that Borges mentions them not to inform, but to overwhelm. The human mind’s aforementioned inability to conceive of the fourth dimension is insuperable, but in generating a sensation of anxiety and confusion by way of a rather Baroque list of four-dimensional shapes, Borges is able to cause a similar effect in the reader. That he goes on to mention the possibility of “universes of two, four, five, six dimensions, and so infinitely until one has exhausted all of the natural numbers” only reinforces this confusion, along with our own hypothesis. (ibid. 510)

A full review of Borges’ scientific output could go on for many more pages, but in the interest of moving our study forward we must now turn to the next chapter. While it is not
necessary to re-state all that has been said in the previous pages before we move forward, certain themes will bear emphasizing. We have shown that Borges and Calvino both received significant educations in scientific and mathematical subject matter, with Calvino as the curious and dutiful son of scientists and Borges openly indulging a voracious appetite for scientific readings. Both Calvino and Borges prolifically produced non-fiction works in which varied elements of science are presented cleanly and clearly for a wide audience – a practice that lies parallel with Calvino’s stated plan for an interdisciplinary and didactic form of fiction, which was outlined in *Six Memos for the Next Millennium*. Both authors recognized and analyzed the subjective and arbitrary foundations of fiction and science, and drew comparisons between these (and other) disciplines in order to promote epistemological parity and encourage an interdisciplinary approach to writing. Reflecting on what we have established here will propel us toward the next chapter, in which we will review the scientific discoveries and concepts that most affected the creative output of Italo Calvino and Jorge Luis Borges, before finally moving into a detailed analysis of their short fictions.
PART I
Part 1, Chapter 1 - The Legacy of Scientific Philosophy

Before we can effectively discuss any aspect of the role of scientific processes in the genesis of fiction, there must first be laid considerable groundwork. While we will eventually encounter the most important scientific discoveries of the last century, we must first achieve a solid philosophical basis upon which to begin our discussion. Commencing with an overview of the deductive logic of Karl Popper, we will then move through Thomas Kuhn’s socio-scientific concept of paradigm shifts and, finally, into the anarchic creativity of Paul Feyerabend – each of whom represents a significant milestone in the development of the philosophy of science.

Karl Popper

In 1935, Austrian philosopher Karl Popper published his first edition of The Logic of Scientific Discovery. Intended to offer a fresh approach to scientific methodology, Popper’s bombshell work was met with both harsh criticism and congratulatory ovation. His argument was simple, yet staggering in its complexity: universal statements, the cornerstone of the traditional, inductive method of science, created logical contradictions in that they could not be conclusively verified simply through observation and subsequent singular statements. (Popper 4) If one considers the example, “I saw three white swans = all swans are white,” the logical fallacy is made readily apparent – one cannot possibly speak about all swans without having seen all swans. Unfortunately, much of humanity’s scientific knowledge had been based on this seemingly functional but ultimately flawed methodology, and Popper’s aim was to convince his contemporaries to abandon the principle of induction. His arguments that inductive logic was superfluous, self-congratulating, rife with inconsistencies and caught in the useless spiral of an
“infinite regress” were met, in turn, with venomous reproach. (ibid. 5) Hans Reichenbach, a Positivist and staunch supporter of inductive logic, said of Popper’s criticisms:

This principle determines the truth of scientific theories. To eliminate it from science would mean nothing less than to deprive science of the power to decide the truth or falsity of its theories. Without it, clearly, science would no longer have the right to distinguish its theories from the fanciful and arbitrary creations of the poet’s mind.” (ibid. 4-5)

Popper, indeed, had begun to highlight a larger problem at the core of all human epistemological enterprises: that what had been assumed to be knowable might remain forever outside of humanity’s grasp.

Popper’s introduction of the “deductive method” of logic suddenly permitted a variable range of credibility for each individual theory. By beginning with a hypothesis and testing its falsifiability, scientists could plumb the limits of what might be verified and conclusively known, rather than trustingly accept that which was assumed to be true based on a limited number of personal observations. Popper hoped also to remove what he referred to as “psychologism” from the scientific enterprise, with the goal of preventing emotion and egotistical pride from muddying the potentially “pure” waters of science. (ibid. 7) He is clear in his intentions:

In rejecting the method of induction, it may be said, I deprive empirical science of what appears to be its most important characteristic; and this means that I remove the barriers which separate science from metaphysical speculation. My reply to this objection is that my main reason for rejecting inductive logic is precisely that it does not provide a suitable distinguishing mark of the empirical, non-metaphysical, character of a theoretical system. (ibid. 11)

Popper’s main assault against inductivism was based on his observation that, despite the Positivists’ apparent desire to eliminate metaphysics from “pure” science, they nevertheless had constant recourse to universal and untenably illogical statements. In doing so, they flirted with the annihilation of natural science along with metaphysics. (ibid. 13)
Popper obviously treads on dangerous ground – to call into question the logical basis of natural science requires strong conviction and a clear mind. In his own words, he establishes a new set of principles:

My business, as I see it, is not to bring about the overthrow of metaphysics. It is, rather, to formulate a suitable characterization of empirical science, or to define the concepts ‘empirical science’ and ‘metaphysics’ in such a way that we shall be able to say of a given system of statements whether or not its closer study is the concern of empirical science… Thus anyone who envisages a system of absolutely certain, irrevocably true statements as the end and purpose of science will certainly reject the proposals I shall make here… I hope that my proposals may be acceptable to those who value not only logical rigour but also freedom from dogmatism; who seek practical applicability, but are even more attracted by the adventure of science, and by discoveries which again and again confront us with new and unexpected questions, challenging us to try out new and hitherto undreamed-of answers. (ibid. 14-15)

And so, in words that might just as well have been spoken in the name of literature or art, Popper reframes the goal of science – not as the pursuit of some eventual, ultimate Truth, but instead as an investigation of the limits of knowledge within the parameters of our senses and mental faculties. He would state later that “an assertion which owing to its logical form is not testable can at best operate, within science, as stimulus: it can suggest a problem.” (ibid. 81) Though some ideas within this new science might spring from a speculative, literary, or even “metaphysical” font, Popper vows to retain a firm footing in the rigors of methodical testing and empirical falsifiability. (ibid. 16-18)

Popper’s defense of his position is lengthy, intricate and well-argued. For the sake of this study, however, we need only turn to one of his most heartbreakingly earnest meditations on epistemology:

The empirical basis of objective science has nothing ‘absolute’ about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or ‘given’ base; and if we stop driving the piles deeper, it is not because we have reached firm
ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure at least for the time being. (ibid. 94)

Echoing the agile approach of Henri Poincaré, Popper acutely delineates the limits of human knowledge by sacrificing humanity’s golden, untouchable truths. Of them, he concludes that “our method of research is not to defend them, in order to prove how right we were. On the contrary, we try to overthrow them.” (ibid. 280)

If we reflect again on the previous quotation of Reichenbach, we can be almost certain that he could not have expected science’s future to increasingly resemble those much-maligned “fanciful and arbitrary creations,” nor would he have foreseen to what extent the poet’s mind and the mind of the scientist might eventually merge into one holistic viewpoint (and perhaps never so much so as in the cases of Borges and Calvino). In turn, Popper’s rejection of universal statements exposed more than he might have even realized about the nature of knowledge – namely, that universal statements are logically inconsistent since one can never make them from within a system.

**Thomas Kuhn**

The limits of knowledge have come to be seen as the central hurdle of modern science, as we will note later when discussing the origins of quantum physics and the study of the anomalies of deep space. As mankind has been faced with an unending series of epistemological foundations, it has occasionally experienced the anguished pangs of paradigm shifts. Thomas Kuhn is credited with coining and defining the concept of the paradigm shift in 1962, in *The Structure of Scientific Revolutions*. Kuhn laid out crisis and conflict as the harbingers of new paradigms – as ineluctable steps in the scientific process, rather than as pitfalls or obstacles. Through the revision, criticism and eventual abandonment of obsolete ideas, mankind can
expand its threshold of knowledge and allow more current visions of the universe to take shape. What makes this concept a particularly compelling companion to an examination of the scientific aspects of the works of Borges and Calvino is Kuhn’s rejection of fixed and unmovable ideas.

“Normal science is a highly determined activity,” he states, “but it need not be entirely determined by rules.” (Kuhn 42) As we outline the history of the philosophy of science, moving steadily through “incommensurable ways of seeing the world and practicing science in it,” (ibid 4) more and more will its shape come to resemble that of an ideal form of literature whose goal is the drawing together of all disciplines.

Kuhn initially lays out his argument by tracing the pattern of crests and troughs that defines the development of scientific ideas:

Normal science repeatedly goes astray. And when it does – when, that is, the profession can no longer evade anomalies that subvert the existing tradition of scientific practice – then begin the extraordinary investigations that lead the profession at last to a new set of commitments… (ibid. 5-6)

New ideas are formed by way of the recapitulation and re-evaluation of “prior fact” across numerous years and multiple minds (ibid. 6). In the same way as scientists whose shared paradigms permit a collaborative or antagonistic effort to bring forth innovation, Jorge Luis Borges and Italo Calvino can be seen as kindred researchers and inventors. Not all scientists – or writers, for that matter – are obliged to shift paradigms simultaneously, which makes it all the more significant that Borges and Calvino appear to have shared a common methodology in their descriptions of reality.

Kuhn does not leave Popper entirely behind in his approach to scientific methodology: “To be accepted as a paradigm, a theory must seem better than its competitors, but it need not, and in fact never does, explain all facts with which it can be confronted.” (ibid. 17-18) Just as we found in Popper, here again is that absence of absolute fact; the best that mankind can hope for
are educated and informed guesses based on observation, experience, and, most crucially, falsification and skepticism. This is not say that there can be no accepted body of knowledge, or that everything need be presumed false – on the contrary, the working corpus of human knowledge grows stronger with every new conflict and each discarded theorem. Kuhn elaborates on such innovations:

When the individual scientist can take a paradigm for granted, he need no longer, in his major works, attempt to build his field anew, starting from the first principles and justifying the use of each concept introduced. That can be left to the writer of textbooks. (19-20)

By extension, can we not reason that the literary writer – the Borges or the Calvino of any given paradigm – embodies a fusion of the roles of textbook writer and scientific innovator? If every work of fiction necessarily generates a provisionally accepted view of the universe, surely its creator must straddle the divide between these disciplines. Further words by Thomas Kuhn bolster this assertion: “Today in the sciences, books are usually either texts or retrospective reflections upon one aspect or another in the scientific life.” (ibid. 20) It will be shown in later chapters of this study that Borges and Calvino were indisputably engaged in this very same pursuit, and found results similar to those of whom we would traditionally refer to as “scientists.” Additionally, and again in line with Kuhn’s observations, scientists no longer write books for the layman – instead, there must be a translation. (ibid. 21) Indeed, the gulf between the public and the specialists is vast. Without the momentum of the populace, though, no scientific idea can move from germ to paradigm. It is in precisely this location that Borges and Calvino (as “writer-scientists”) reside. Their recapitulations of and elaborations on established elements of the scientific paradigm have the functions of both educating a reading public and simultaneously modifying and manipulating the framework of the paradigm itself. Throughout
their oeuvres, Borges and Calvino generated new methodologies and willingly disposed of obsolete ideas, all in the name of descriptive efficacy.

Turning again to Kuhn’s words, we can move forward into a discussion of the often-accidental nature of innovation:

No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others. Instead, normal-scientific research is directed to the articulation of those phenomena and theories that the paradigm already supplies. (ibid. 24)

Is this not – again – an analogue to the process and industry of literature? How many writers can be said to have established wholly new genres? Kuhn goes on to say that

a part of normal theoretical work… consists simply in the use of existing theory to predict factual information of intrinsic value. The manufacture of astronomical ephemerides, the computation of lens characteristics, and the production of radio propagation curves are examples of problems of this sort. (ibid. 30)

This is an equivalency to the nearly endless and predictable elaborations of genre that appear on bookstore shelves and online shopping carts – one need only glance at the flush of red, blue and silver swathing the familiar-sounding titles of paperbacks in the Romance aisle at an airport bookstore, or the repeated themes summarized in the front jackets of myriad best-sellers, to get a sense that innovation is not as easily found as one might think. This is not say that such examples of genre elaboration are not needed – on the contrary, they steadily swell the paradigm to a breaking point, enabling each aspect of “normal” research to eventually reach a dead-end, requiring a shift in perspective to provide resolution. Kuhn confirms this process, stating that “extraordinary problems are not to be had for the asking. They emerge only on special occasions prepared by the advance of normal research.” (ibid. 34)
To render this argument more salient, we can take an example from Calvino’s Mr. Palomar to represent an illustration of the process through which “normal science” becomes more and more complex, reaches a paradox, and finally requires a paradigm shift to resolve its inconsistencies. Being a simple story of observational research at its core, Palomar’s journey begins with the protagonist “reading a wave” – he sits on the shore and watches the surf, gradually attempting to focus his gaze on individual waves, and then on the discrete parts of each wave. As he tries to delineate where exactly one wave ends and another begins, he is confounded by the interplay of other waves, people in the surf and the eventual understanding that in trying to see one wave he loses his focus on the others (which is in itself a version of Heisenberg’s Uncertainty Principle, to be covered in the next chapter). As this short tale comes to a close, Palomar loses his patience and walks off, “tense and nervous as when he came, and even more unsure about everything.” (Calvino 8). Palomar has encountered a difficult problem in the midst of what appeared to be a very elementary observational exercise. Kuhn explains that “even the project whose goal is paradigm articulation does not aim at the unexpected novelty.” (Kuhn 35) It is in precisely this way that normal science can stumble upon a paradigm-changing event.9

We have said much about the methodological properties of “normal science,” but what of its social aspects? Like literature, science also can affect the world in which it works, and in some ways the culture of this world is reflected in the science that it generates. Kuhn astutely notes that “a paradigm can…even insulate the community from those socially important

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9One concession that must be made in science’s defense is that, unlike science’s constant negotiation with the material world, writers are free, in most senses, to follow whimsy rather than fact, thereby facilitating wild experimentation with relative immunity to physical consequences. But then even this division, when we arrive at our discussion of Paul Feyerabend’s Against Method, may simply dissolve into so many scattered atoms. – MR
problems that are not reducible to the puzzle form, because they cannot be stated in terms of the conceptual and instrumental tools the paradigm supplies.” (ibid. 37) He goes on:

The scientist must, for example, be concerned to understand the world and to extend the precision and scope with which it has been ordered… And, if that scrutiny displays pockets of apparent disorder, then these must challenge him to a new refinement of his observational techniques or to a further articulation of his theories. (ibid. 42)

One can posit that this same approach applies directly to the cases of Jorge Luis Borges and Italo Calvino. When considering intricate, mathematically-driven stories like “The Library of Babel” or “The Garden of Forking Paths,” it is not difficult to see Borges as a practitioner of such “extraordinary science,” initiating a movement through and past the tropes and structures of a former paradigm; just as easily could one consider Calvino a Borgesian “scientist” through his innovative fusion of scientific thought and literary innovation. Perhaps in this way, by modeling the techniques of science, literature succeeds in joining the scientific conversation already in progress.

Kuhn provides further evidence that writers and scientists are, ultimately, not so different;

One is at liberty to suppose that somewhere along the way the scientist has intuitively abstracted the rules of the game for himself, but there is little reason to believe it. Though many scientists talk easily and well about the particular individual hypotheses that underlie a concrete piece of current research, they are little better than laymen at characterizing the established bases of their field, its legitimate problems and methods. (ibid. 47)

This idea – that scientists do not belong to an elite group but, rather, simply demonstrate an advanced knowledge of some highly particular aspect of a largely decentralized whole – throws open the gates to the realm of science and allows those who craft literature to enter freely, and with just as much claim to accuracy and authority as those who have perennially dwelt there. It would seem, also, that our granting both Borges and Calvino the titles of “literary scientists” cannot be met with anything but acceptance while keeping Kuhn’s words in mind.
And what of the “revolutions” named in the title of Kuhn’s most famous work? What effects do they have on the world around us? We are told that, on an immediate level, they are mundane. “There is no geographical transplantation; outside the laboratory everyday affairs usually continue as before. Nevertheless, paradigm changes so cause scientists to see the world of their research-engagement differently.” (ibid. 111) These subtle effects of internal revolutions mimic those of literary innovations – while they may not visibly affect the outside world, they do reshape the world-view of those who are privy to their occurrences. Additionally, after the dust has cleared and a new discovery has taken hold of those within the paradigm, the writing begins anew; textbooks are revised and generated; articles and arguments are penned and published (ibid. 144). The foundation of all of science’s pursuits rests firmly on literary bedrock, then: that of the written word.

The latter portion of Kuhn’s *The Structure of Scientific Revolutions* emits even more exemplary ideas that support our argument that the writing of Borges and Calvino can be ascribed equally to the dimensions of science and literature. We are asked whether we can “very much depend upon a *definition* of science,” and whether such a definition can “tell a man whether he is a scientist or not.” (ibid. 160) Kuhn also insists that “science is any field in which progress is marked,” which would allow any number of human endeavors to be potentially considered “sciences.” In a final stroke of open-minded clarity, Kuhn confesses in his postscript to what the reader has implicitly understood all along:

> To the extent that the book portrays scientific development as a succession of tradition-bound periods punctuated by non-cumulative breaks, its theses are undoubtedly of wide applicability. But they should be, for they are borrowed from other fields. Historians of literature, of music, of the arts, of political development, and of many other human activities have long described their subjects in the same way. (ibid. 208)
Paul Feyerabend

Paul Feyerabend, an Austrian philosopher and physicist, will serve as the final character in this brief overview of relatively recent scientific philosophy, and rightly so, as his “anything goes” approach to framing scientific progress and epistemic validity will deliver us to the very doorstep of the fictive literary act as embodied in Calvino and Borges. His controversial Against Method (1975) was an attempt to illustrate that all great scientific discoveries do not stem from a rigid, dogmatic reading of methodological rules, but rather occur only when the established order has been suspended, broken or bent to the will of the scientist. Not intended as an assault on the work of scientists, Feyerabend’s work was rather meant to be a harsh light shone on the hegemony of intellectual ideology. In his words: “Single-mindedness in pursuit of any goal, including truth and understanding, yields great rewards. But single vision is folly if it makes you think you see THE truth, the one and only truth. So, ‘anything goes.’” (Feyerabend XIII) Even the precious position that science has held in society as a bastion of empirical fact is called into question in Feyerabend’s thesis – instead, he proposes an equalization of all disciplines and fields, so that none might wield too much influence on the public and no potentially fruitful hypothesis might be ignored or cast aside due to aesthetic or personal prejudice.

Some of the most important formal properties of a theory are found by contrast, and not by analysis. A scientist… must adopt a pluralistic methodology… Experts and laymen, professionals and dilettanti, truth-freaks and liars – they are all invited to participate in the contest and to make their contribution to the enrichment of our culture. (ibid. 13)

As we will see in chapters to come, this approach mirrors the encyclopedic and broadly inclusive styles of both Borges and Calvino and epitomizes the ideal, multifaceted “literature” that Calvino optimistically envisioned for the future.
But where are the rules in Feyerabend? How is anything to be considered “proven” if truth itself is no longer a stable foundation upon which to judge theories? The author’s admittedly idealist and Marxist approach to the business of science does not leave us with many concrete answers. At turns playful and arrogant, sober and humanistic, Feyerabend did not set out to rewrite or replace the rules of science. (ibid. 16) Instead, he strove to supply modern thinkers with a larger toolkit with which to craft their ideas. His seems to be very much a philosophical battle, which, in the end, is probably not such a bad thing for a philosopher. His feelings on pluralist methodology are clearly stated:

There is no idea, however ancient and absurd, that is not capable of improving our knowledge. The whole history of thought is absorbed into science and is used for improving every single theory. Nor is political interference rejected. It may be needed to overcome the chauvinism of science that resists alternatives to the status quo… A scientist who is interested in maximal empirical content, and who wants to understand as many aspects of his theory as possible, will adopt a pluralistic methodology, he will compare theories with other theories rather than with ‘experience’, ‘data’ or ‘facts’, and he will try to improve rather than discard the views that appear to lose in the competition. For the alternatives, which he needs to keep the contest going, may be taken from the past as well. As a matter of fact, they may be taken from wherever one is able to find them – from ancient myths and modern prejudices; from the lucubrations of experts and from the fantasies of cranks… The separation between the history of a science, its philosophy and the science itself dissolves into thin air and so does the separation between science and non-science. (ibid. 27)

There is not much to add to such a passionate exhortation of the need for creativity and imagination in the hard sciences, except to acknowledge that, at this point, Feyerabend has eliminated many of the divisions between the realms of fact and fiction – myth can become reality, and a raving lunatic can be a “scientist,” even if only in name. Surely not all of this is meant to be taken quite so literally, but somewhere therein we find the same spirit of interdisciplinary ingenuity and curious, freeform experimentation that has allowed the greatest successes of both Italo Calvino and Jorge Luis Borges to come into existence.
This is not to say that Paul Feyerabend’s legacy is all starry-eyed idealism – quite the contrary. Throughout *Against Method*, Feyerabend rails against Karl Popper’s standards for falsifiability and reason, largely for their “inhuman” and rigid characteristics. Referring to Popper’s project as “specialized, formalistic and elitist, and devoid of the concern for human happiness,” (ibid. 27) Feyerabend criticizes his erstwhile colleague for limiting the freedom of the scientist to choose ideas at will and as needed according to the terms of his own process and his own imagination. He noted that “such a procedure may satisfy the school philosopher, who looks at life through spectacles of his own technical problems and recognizes hatred, love, happiness, only to the extent to which they occur in these problems. But,” he continues, “if we consider human interests and above all, the question of human freedom…then we are proceeding in the worst possible fashion.” (ibid. 156) In his own defense (had he still drawn breath) Popper might have argued that Feyerabend’s approach quite obstinately made no attempt to pose counter-arguments against competing theories just as it nevertheless embraced other theories without testing their limits of falsifiability, thereby leaving the door open to shaky science and a total lack of rigor and accountability. (ibid. 153) Popper earnestly attempted to make the best of a scientific and human condition in which nothing is truly knowable, as he himself would have freely admitted. Nevertheless, Feyerabend’s well-intentioned spirit is the closest kin to Calvino’s humanist enterprise and, at certain moments, of Borges’ touching and delicately intimate humanity.

In any case, if one suspends for a moment their judgment of the practical aspects of Feyerabend’s program and instead allows him the indulgence of illustration, he does succeed in expressing the nuanced basis of his fledgling system. For example, in a brief summarization of the history of science Feyerabend recalls that both Aristotle and Ptolemy agreed that the Earth
was a stationary object in the ether, and that all other bodies revolved in relation to it. This position was in direct opposition to that of their allegedly quirky but esteemed predecessor, Pythagoras, who had held that it was in fact the Earth that moved in relation to other celestial bodies. Much later, Nicolas Copernicus exhumed this dead Pythagorean model in order to support and prove his own heliocentric celestial model. By rejecting the perennially accepted fact that the Earth was a stationary object and by reconnecting with a previously discarded theory, Feyerabend posits, Copernicus reached into the past in order to carry science into the future. (ibid. 29) Feyerabend makes similar arguments in favor of a pluralistic methodology, drawing examples from Chinese and Western medicine (ibid. 31) as well as the arts (ibid. 32). It is precisely this unrestrained and inclusive spirit that Feyerabend sought to express in Against Method.

Knowing what we do about Feyerabend after this brief and necessarily incomplete introduction, one might be left with the impression that, as he opines, science is much more “sloppy” or “irrational” than what its methodological visage might suggest (ibid. 160). True or not, these two terms are perhaps unnecessarily negative. In our further discussions of scientific concepts and the literature of Calvino and Borges, we will instead prefer to demonstrate the openness and freedom that Feyerabend’s approach provides to both disciplines.
Part 1, Chapter 2 – Foundational Physics

Approaching the Modern Age

In an essay entitled “The Book of Nature in Galileo,” written in 1985 and later published in English in a collection of works entitled Why Read the Classics?, Italo Calvino cites what he considers to be Galileo Galilei’s most potent maxim: “Nature is written in a mathematical language.” (Calvino 83) The link between these two concepts, Calvino explains, lies in the divergent notions of world and alphabet; “alphabet” is to be understood as a combinatory system of minimal semiotic elements that carry no meaning of their own, but instead are defined relationally and provisionally within a “world.” The “Book of Nature,” according to Galileo, was written in a new alphabet that differed substantially from those already established by humanity. This new system of signs, once understood and decoded, would ideally reconcile the reality of an ever-changing Earth with what were considered to be, for Galileo and some of his contemporaries, the immutable and constant heavens. (ibid. 88) The key to the universe, it seemed, was within reach of those who were patient and intelligent enough to grasp it.

This concept is not the only one that Calvino gleaned from Galileo. During a television interview in 1968, Calvino discussed his position that Galileo had perhaps been Italy’s greatest writer of prose. A prime consideration behind this opinion was the observation that the legendary astronomer had harnessed scientific language “not as a neutral utensil, but with literary awareness, with a continuous commitment that [was] expressive, imaginative and even lyrical.” (Uses of Literature 31) Galileo – an observational scientist and theorist first – regarded the world and universe in an “ideal” way (ibid. 32) that was nourished by literary culture. He had succeeded, in Calvino’s estimation, in merging the often divisive disciplines of science and
literature, creating all at once a literary tradition that both stimulated the imagination and cultivated concrete knowledge in the reader. Calvino, in his own writing, found “nourishment in Galileo, in his precision of language, his scientific-poetic imagination, his posing of conjectures.” (ibid. 32) Roger Newton, a scientist and scholar to whom we will have recourse at several moments in our study, echoes these same notions and develops them further.

In his mathematical discussions he distinguishes between finite, infinitesimally small, and infinitely large quantities, without flinching from paradoxes that arise and appear unresolvable. On the subject of infinite quantities, for example, he points out that such concepts as “less than,” “greater than,” and “equal to” are not necessarily applicable, which he exemplifies by showing that the infinite set of natural numbers can be put into one-to-one correspondence with the set consisting of their squares. These are problems with a definitely modern flavor that would preoccupy mathematicians in the nineteenth century. (Newton 83-4)

Again, in 1985 – just prior to his untimely death – Italo Calvino presented further observations on Galileo in the notes for a lecture entitled “Quickness.” “For [Galileo], good thinking means quickness, agility in reasoning, economy in argument, but also the use of imaginative examples.” (Six Memos 43) It should not strike us as strange, then, that Calvino went on to praise another major literary influence in this same essay, and for precisely these same qualities. “What I particularly wish to stress is how [Jorge Luis] Borges achieves his approaches to the infinite without the least congestion, in the most crystalline, sober and airy style. In the same way, his synthetic, sidelong manner of narration brings with it a language that is everywhere concrete and precise…” (ibid. 50-51) In another essay entitled “Multiplicity,” Calvino restates his praise for Borges. “I love his work because every one of his pieces contains a model of the universe or of an attribute of the universe (infinity, the innumerable, time eternal or present or cyclic); because they are texts contained in only a few pages, with an exemplary economy of expression…” (ibid. 119) Calvino’s affinities for both Borges and Galileo seem, in fact, to be based on largely the same criteria. In apparent support of this comparison, Galileo
shows up in Borges’ writing as well. A brief non-fiction piece entitled “On the Cult of Books” cites Galileo’s aforementioned “natural alphabet” as an analogue to Francis Bacon’s postulation of a divine “abecedarium naturae.”

To simply state that Galileo’s influence on literature was far-reaching would be barely sufficient; Calvino confidently asserted that Galileo – in the same way as Italy’s crown jewel, Dante Alighieri – had “tried to construct an image of the universe by means of the written word,” thereby initiating a “deep-rooted vocation in Italian literature.” (Uses of Lit. 32) In speaking about his own writing, Calvino did not miss a chance to render thanks unto Galileo: “From time to time I get the feeling that the road I am taking is leading me back to the true but forgotten source of the Italian tradition.” (ibid. 33) The unique character of Calvino’s literary production, seated astride both the creative exercises of literature and the intellectual rigor of science, can be traced along a direct line back to the infamous Pisan astronomer.

Though beloved by Calvino and Borges, Galileo was not the only pre-modern thinker to attempt to construct an image of the universe as it truly was. In later years, the scientific world would be shaken by the erratic and fragmentary musings of Blaise Pascal, a French philosopher, polymath and engineer. While harboring an undeniably Christian and theist perspective on the nature of the universe, Pascal also initiated a courageous and early departure from the perception that the universe was closed, solid and eventually knowable, effectively overturning centuries of scientific and philosophical teleology. The editor and translator of a collection of Pascal’s Pensées, A.J. Krailsheimer, explains that Pascal was focused on the image of Christ as the redeemer of man’s wretchedness, but also toiled to weaken the faith that could be held in reason’s power; “The pattern, not only of the Pensées, but of all Pascal’s religious writing, is the stark contrast between man in his state of fallen nature and in a state of grace.” (Pensées XXI)

This perspective places Pascal at a midpoint between man’s perennial trust in the universe’s ultimate coherence (by way of a supernatural being) and the implicit agnosticism of modern science. Pascal himself lamented that “only reason can persuade reason of its own inadequacy,” (ibid. XXIV) and in doing so he vocalized the same struggle that would be later undertaken by more modern thinkers, including Kurt Gödel, Erwin Schrödinger and Henri Poincaré. That something stands in the way of our full understanding of the universe – be it an omnipotent God or a yawning, incomprehensible infinity – is a tremendously forward-thinking concept for any human being, let alone a devoutly religious man of the seventeenth century.

The *Pensées* themselves are a collection of Pascal’s philosophical fragments and thoughts, originally arranged numerically on lengths of string according to theme and demonstrating his intellectual and emotional struggles. They are widely varied in subject matter and tone, though many inevitably return to a chorus pondering the weakness of reason and its uselessness as a foundation for thought, like fragment number 188: “Reason’s last step is the recognition that there are an infinite number of things which are beyond it.” (ibid. 56) Others focus on the parameters of infinity and man’s hopelessness within such immensity, including number 199: “Nature is an infinite sphere whose center is everywhere and circumference nowhere… What is a man in the infinite? …A nothing compared to the infinite, a whole compared to nothing, a middle point between all and nothing, infinitely remote from an understanding of the extremes.” (ibid. 60-61)

Despite having predated modern science by at least two centuries, Blaise Pascal unwittingly prefigured several current scientific conjectures. Number 199 of his *Pensées*, by far the richest fragment for our own purposes, cleaves rather closely to what will be seen in our later discussion of Georg Cantor’s transfinite set theory.
Thus we see that all the sciences are infinite in the range of their researches, for who can doubt that mathematics, for instance, has an infinity of infinities of propositions to expound? They are infinite also in the multiplicity and subtlety of their principles, for anyone can see that those which are supposed to be ultimate do not stand by themselves, but depend on others, which depend on others again, and thus never allow of any finality… In the perspective of these infinities, all infinites are equal and I see no reason to settle our imagination on one rather than another. (ibid. 62-64)

Cantor’s so-called “continuum hypothesis,” intended to establish a hierarchy of theoretical “sets” of infinities, was never proven. Two hundred years prior, Blaise Pascal had unknowingly defined the terms of Cantor’s paradox by demonstrating the impossibility of differentiating between separate or unique infinites. Pascal had tapped into the spirit of a mathematical quandary from the distant future; perhaps fittingly, he also foreshadowed Kurt Gödel’s famous rebuttal of Cantor’s theory, embodied fully in what has come to be known as Gödel’s “Incompleteness Theorem”: “If man studied himself, he would see how incapable he is of going further. How could a part possibly know the whole?” (ibid. 64) As we will see in coming chapters, this simple statement channels the truest sense of what would become Gödel’s bogglingly intricate logical exercise.

Pascal’s thoughts are not all mired in negativity, though. At times he reaches into other dimensions and realities, igniting a spark would eventually become a conflagration in Hugh Everett III’s “Many-World’s Interpretation of Quantum Mechanics” in 1957; “I want to show [man] a new abyss,” said Pascal. “I want to depict to him not only the visible universe, but all the conceivable immensity of nature enclosed in this miniature atom. Let him see there is an infinity of universes, each with its firmament, its planets, its earth, in the same proportions as in the visible world…” (ibid. 61) Pascal can also be seen reaching for the void in a description of something akin to a black hole and, in an abstract sense, Borges’ legendary “Aleph”; “Do you believe that it is impossible for God to be infinite and indivisible? –Yes– Very well, I will show
you something infinite and indivisible: it is a point moving everywhere at an infinite speed. For it is one and the same everywhere and wholly present in every place.” (ibid. 126) In a practically Thoreauvian moment, Pascal merges the concept of the infinite physicality of God with the physics of the darkest, densest and most mysterious places of the universe. Borges, in his own readings, had encountered Pascal and summarized him in this way:

In that dejected century, the absolute space that inspired the hexameters of Lucretius, the absolute space that had been a liberation for Bruno was a labyrinth and an abyss for Pascal. He hated the universe and yearned to adore God, but God was less real to him than the hated universe. He lamented that the firmament did not speak; he compared our lives to the shipwrecked on a desert island. He felt the incessant weight of the physical world; he felt confusion, fear, and solitude; and he expressed it in other words: “Nature is an infinite sphere, the center of which is everywhere, the circumference nowhere.” That is the text of the Brunschvieg edition, but the critical edition of Tourneur (Paris, 1941), which reproduces the cancellations and hesitations in the manuscript, reveals that Pascal started to write the word effroyable: “a frightful sphere, the center of which is everywhere, and the circumference nowhere.” (SNF 353)

This deep reading proves Borges’ familiarity with Pascal’s philosophical system and psychological struggles, and, in highlighting Pascal’s writing process, demonstrates Borges’ keen critical eye.

In our own study, of course, all of Pascal’s magnificent rhetoric would be for naught if it did not lead us back to the interdisciplinary spirit of Italo Calvino and Jorge Luis Borges. In number 512 of the Pensées, Pascal presents a binding tie – the hopeful vision of the mathematician fused with the creative thinker: “All mathematicians would therefore be intuitive if they had good sight, because they do not draw false conclusions from principles that they know. And intuitive minds would be mathematical if they could adapt their sight to the unfamiliar principles of mathematics.” (ibid. 182) Just as Calvino would later appeal for the cultivation of an ideal thinker versed in both science and literature, echoing as well the hope of
C.P. Snow and the spirit of the erudite and endlessly curious Borges, so did Pascal recognize the importance of drawing intellectual inspiration from a plethora of sources and fields of study.

In the interest of delving deeper into these varied fields of study, it will be beneficial for us to allow a brief historical introduction to the tenets of thermodynamics, with a specific focus on the aforementioned concept of entropy that lies at its core. According to Columbia University physicist Brian Greene, author of *The Fabric of the Cosmos*, “the notion of entropy was first developed during the industrial revolution by scientists concerned with the operation of furnaces and steam engines, who helped develop the field of thermodynamics.” (Greene 151)

Thermodynamics, in turn, is the branch of physical science that deals with heat and its relationship to energy transfer – Roger G. Newton provides an extremely concise and effective description: “[Thermodynamics] dealt with the behavior of heat, its conduction through objects, and its transfer from one body to another, as well as its relation to other phenomena such as pressure and volume changes of gases, rather than with its fundamental nature.” (Newton 144)

The boundaries of thermodynamics can be expressed in a set of four laws, although Newton goes on to delineate their relative importance:

> The rest of thermodynamics lays down detailed rules governing how the flow of heat through or into a body depends on the properties of the material making it up, the behavior of fluids when their temperature, pressure or volume changes, and the way the state of a substance changes, from a gas to a liquid or a solid or vice versa, as its temperature or pressure changes. However, the formulation of the first and second laws is the most important achievement of thermodynamics. (ibid. 152)

This second law will also be of the most use to us in our own study of literature and science. This law is specifically concerned with entropy, which is succinctly (and perhaps simplistically) defined as being a measure of the amount of disorder in a physical system.

According to the second law of thermodynamics, “there is a natural evolution toward greater disorder, since disorder can be achieved in so many more ways than order. In the
language of entropy, this is the statement that physical systems tend to evolve toward states of higher entropy.” (Fabric 154-155) Michio Kaku, another renowned physicist and a CUNY faculty member, adds another crucial detail to the interpretation of thermodynamics’ second law: “any process creates a net increase in the amount of disorder (entropy) in the universe.” (Hyperspace 304) In parallel terms: absolutely any action taken in the universe creates an increase in entropy, be it a supernova or a sneeze. While a statement of this kind appears to leave scarcely any room for exceptions, there is a possibility for the unlikely to occur.

…It is important to remember that we are dealing with probabilities and statistics, not deterministic predictions of the behavior of individual systems. In the course of the development of a system consisting of many particles, such as a gas, the entropy varies and fluctuates, sometimes wildly. The states called equilibrium are by far the most probable because there are so many of them, all practically indistinguishable from one another. The entropy in these states is maximal. Any individual state far from equilibrium is very improbable – it has low entropy – because there are very few states like it or almost like it. Such states are always set up by external intervention; they almost never arise spontaneously in an isolated system. (Newton 185)

“Almost never,” while certainly on the far edge of the odds, is in no way an utter prohibition – this notion brings us once again to a locus shared by both science and fiction: just as carefully controlled scientific experiments have the capacity to bring such improbable low-entropy states into existence, so do works of imaginative, narrative writing.

The increase of entropy, then – the statistically probable movement from a low-to-high entropy state – seems to echo the multiplication of elements and the increasing tension and confusion that we find in many narratives by both Borges and Calvino – Borges’ “The Lottery in Babylon” and scenes involving Calvino’s tortured Mr. Palomar come to mind most readily. Much of the writing found in these two authors’ oeuvres might be grouped under the heading of (to coin a term) *entropic* writing; in other words, writing that tends toward increasing states of disorder *and lacks a subsequent reversal of this increase in disorder.*
Stephen Hawking, the English physicist and author of the legendary work of popular science *A Brief History of Time*, provides more clarity on the probabilistic and volatile nature of thermodynamics’ dominant rule. “The second law of thermodynamics has a rather different status than that of other laws of science, such as Newton’s law of gravity, for example, because it does not hold always, just in the vast majority of cases.” (Hawking 107) Brian Greene clarifies this admittedly obtuse point: “For things with many constituents, going from lower to higher entropy – from order to disorder – is easy, so it happens all the time. Going from higher to lower entropy – from disorder to order – is harder, so it happens rarely, at best.” (Elegant Universe 158) Spilled milk does not independently flow back into the glass; gases released from a tank do not regroup and return to their original container; in short, the complex does not routinely become the simple. Though statistically this *can* occur, the more numerous the constituents in a system the less probable it becomes. However unlikely, Roger Newton reinforces the possibility of such a reversal of entropy:

…A system in a state of low entropy will, as Poincaré decreed, eventually return to an almost identical state of equally low entropy, but “eventually” here means that the waiting period for the recurrence to happen in an inevitable fluctuation is many times longer than the age of the universe. This is not a wild guess but can be actually calculated. (Newton 186)

Again, in the same way that the probability and characteristics of such a state can be calculated through scientific experimentation, so does the fictive process allow us to bring into existence and witness – through whatever mental exercise – varying states of disorder.

In Newton’s estimation, the second law of thermodynamics “introduced an entirely new notion into physics... It contained an arrow of time, defined by the inexorable and irreversible increase in entropy. The concept of time’s irreversible flow, popular and influential in philosophy and literature, had finally found its way into physics.” (Newton 153) Here, the point of dialogue between literature and science is made exceptionally clear. The notion that, over
time, elements (whether real or fictional) become increasingly disordered on a relational level. This sits in perfect alignment with the complex and interlaced weave of elements in the works of Italo Calvino and Jorge Luis Borges; just as human experience can only be lived along an increasingly disordered “arrow of time,” so only can it be represented. As Hawking tells us, “just like a computer, we must remember things in the order in which entropy increases.” (Hawking 151)

Beginning typically with a tight, compact image, theme or nucleus and gradually spiraling out into often universal or epic scopes, the fictions given to us by these two writers reflect the same macroscopic dispersal of energy that has been playing itself out on a grand scale across our randomized cosmos since the occurrence of the Big Bang.

As we established in the preceding chapter, Borges and Calvino were not strangers to such advanced scientific and mathematical concepts. In an article published in Corriere della sera on January 23, 1976, Calvino serenely provided readers with an accessible explanation of the primary laws of thermodynamics.

L’irreversibilità del tempo ha due aspetti. L’uno si manifesta in tutti quei processi… che implicano un passaggio da stati più semplici e uniformi a stati più complessi e differenziati… L’altro aspetto è quello dello sciogliersi della zolletta di zucchero nel caffè, del volatilizzarsi del profumo fuori del flacone aperto, del degradarsi dell’energia in calore: qui la <<freccia del tempo>> segna la direzione opposta: quella della crescita del disordine, dell’entropia, della dissoluzione dell’universo in un pulviscolo senza forma.11

Borges, as was briefly shown in the preceding chapter, demonstrated a confident familiarity with the concept of entropy in several works – in the cases of “Raymond Llull’s Thinking Machine” and “The Doctrine of Cycles,” he even mentions the concept by name. “Entropic writing” would therefore appear to be a particularly apt description, based on both the subject matter chosen by both authors as well as their own personal knowledge.

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Henri Poincaré

Henri Poincaré, through his work in mathematics and physics, was a primary architect in a field of research that would eventually come to be known as *chaos theory* (a discipline that will be analyzed in detail during the final chapter of this study). He excelled in all branches of science and philosophy and was widely regarded as a brilliant and inventive thinker. A man of letters, he also served as director of l’Académie Française and President of l’Académie des Sciences, and is even said to have had an influence on both Albert Einstein and Pablo Picasso. Poincaré outlined his own clearly-defined methodology of thought in *Science and Method*, a 1908 treatise on the philosophy of science. Through anecdotes and self-analysis, he demonstrated that when he found himself unable to overcome a particular mathematical quandary, his subconscious mind would continue to process combinations of elements while he engaged in other activities. Eventually, and at a completely arbitrary time, the correct answer would suddenly come to him as if in a flash, and he would rush off to verify it. In environs ranging from a seaside stroll to attending a geological conference, while serving in the military, and even during fitful attempts to sleep after having drunk too much coffee, Poincaré received dispatches from his subconscious, which appeared to have been working on problems even as he remained mentally idle. He eventually came to form the opinion that the mind, nourished by periods of rigorous study, will then bear its best fruit when left to silently process combination after combination of elements in the background. Italo Calvino appears to have shared Poincaré’s understanding of the mind’s internal combinatorial processes, as we can see in his 1985 essay “Visibility”;

> The poet’s mind, and at a few decisive moments the mind of the scientist, works according to a process of association of images that is the quickest way to link

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and to choose between the infinite forms of the possible and the impossible. The imagination is a kind of electronic machine that takes account of all possible combinations and chooses the ones that are appropriate to a particular purpose, or are simply the most interesting, pleasing, or amusing. (Six Memos 91)

Indeed, how can the mind know which combinations are the best? Poincaré departs from Calvino’s more playful adjectives to define the desired arrangements of elements as those that are “useful”:

What, in fact, is mathematical discovery? It does not consist in making new combinations with mathematical entities that are already known. That can be done by anyone, and the combinations that could be so formed would be infinite in number, and the greater part of them would be absolutely devoid of interest. Discovery consists precisely in not constructing useless combinations but in constructing those that are useful, which are an infinitely small minority. (Method 50-51)

Soon after, Poincaré attempts to resolve the potential psychologism that he has created by acknowledging the role of personal choice in scientific enterprise:

It may appear surprising that sensibility should be introduced in connexion with mathematical demonstrations, which, it would seem, can only interest the intellect. But not if we bear in mind the feeling of mathematical beauty, of the harmony of numbers and forms of geometric elegance. (ibid. 59)

Poincaré is not shy on this point; on several other occasions he presented a sentiment akin to the idea that “any fact can be generalized in an infinite number of ways, and it is a question of choice.” (Science and Hypothesis 146) The best scientist, then, is the one who can tease out from all of the useless combinations the one that is simplest, most elegant and most useful, and then prove it using a rigorous process of numeric or quantitative verification.

Though not immediately apparent, this aesthetic turn highlights the first point of contact between Poincaré’s scientific approach and the provisional procedures of literary creation. In an aforementioned work from 1902 entitled Science and Hypothesis, Poincaré confidently posits an unpopular truth regarding the foundations of scientific knowledge, and in fact of all knowledge.
Whence are the first principles of geometry derived? Are they imposed on us by logic? Lobatchewsky, by inventing non-Euclidean geometries, has shown that this is not the case. Is space revealed to us by our senses? No: for the space revealed to us by our senses is absolutely different from the space of geometry. Is geometry derived from experience? Careful discussion will give the answer – no! We therefore conclude that the principles of geometry are only conventions. (ibid. XXV)

Conventions, then, and not absolute, universal truths, are the wages of all human scientific endeavors, and in this admission the line between art and science, between poetry and geometry, between fiction and fact is all but annihilated. The worlds invented by Calvino in his *Cosmicomics* and the magnificent society shown to us by Borges in “Tlön, Uqbar, Orbis Tertius” are grown from the same seed as Einstein’s relativity and the accepted laws of thermodynamics, a position that is only reinforced by Poincaré’s next elaboration:

"Every conclusion presumes premises. These premises are either self-evident and need no demonstration, or can be established only if based on other propositions; and, as we cannot go back in this way to infinity, every deductive science… must rest upon a certain number of indemonstrable axioms." (ibid. 35)

The *a priori* roots that anchor the whole of science do not sprout from some absolute source – they come from man, in the same way as all literature, all music and all art. The inventive scientist, then, is as much an artist as he is an engineer, and he must rely on his imagination just as much as he does his logical faculties. Calvino would attest to this notion in the very same essay that was cited previously: “…The imagination, while following channels other than those of scientific knowledge, can coexist with the latter and even assist it, indeed be a phase the scientist needs in order to formulate his hypothesis.” (*Six Memos* 88) One need only reflect on the magnificent insights that were the products of Poincaré’s seaside strolls and daydreams to find evidence of this connection between the imaginary and the rational.

This topic, scandalous to many in the realm of quantitative science, should not be seen as an affront to the validity of the incredible discoveries that scientific enterprise has yielded. On
the contrary, it is actually a means to elevate literature to the same level and, perhaps, to allow a more porous flow between the two disciplines, fostering further inspiration. Creative freedom is indeed the hallmark of both fields, and to this very point Poincaré spoke on a number of occasions. Regarding the interplay between the subconscious and the conscious mind, he said that: “The rules of these calculations are strict and complicated; they demand discipline, attention, will and consequently consciousness. In the subliminal ego, on the contrary, there reigns what I would call liberty…” (Method 63) Careful enough not to invalidate his entire enterprise, however, Poincaré had also previously cautioned against taking this concept of liberty too far. “Some people have been struck by this characteristic of free convention which may be recognized in certain fundamental principles of the sciences. Some have set no limits to their generalizations, and at the same time they have forgotten that there is a difference between liberty and the purely arbitrary.” (Hypothesis XXIII) There is, then, the requirement in science to at least temporarily agree to the established principles, even if they are understood to represent not absolute truths but rather the current limits of human understanding.

Our choice among all possible conventions is guided by experimental facts, but it remains free, and is only limited by the necessity of avoiding every contradiction… What, then, are we to think of the question: Is Euclidean geometry true? It has no meaning. We might as well ask if the metric system is true, and if the old weights and measures are false. One geometry cannot be more true than another; it can only be more convenient. (ibid. 50)

Effective literature carries the same requirements of consistency and measure, and also expects, in the reader as much as in the writer, a mutual acceptance of the parameters – the conventions – of the exercise. There is no getting around it – “Principles are conventions and definitions in disguise.” (ibid. 138)

In keeping with the idea of an “effective” literature, we might also dwell a moment on the reciprocal concept of “effective” science. Like the discarded drafts that precede a completed
work of fiction (or a completed dissertation, for that matter), a scientific principle need not be ironclad and flawless in order to be of use to the business of inquiry. Instead, according to Poincaré, the role of the principle is to be disproved in the service of progress.

The ephemeral nature of scientific theories takes by surprise the man of the world. Their brief period of prosperity ended, he sees them abandoned one after another; he sees ruins piled upon ruins; he predicts that the theories in fashion to-day will in a short time succumb in their turn, and he concludes that they are absolutely in vain… His scepticism is superficial; he does not take into account the object of scientific theories and the part they play, or he would understand that the ruins may still be good for something. (ibid. 160)

“Effective” science, then, is often wrong; or rather, it suffers an artifice only so long as it is fruitful before abandoning it in favor of yet another artifice. What can be known through science is always clipped by this upper limit, about which Kurt Gödel opined and against which Georg Cantor raged. Poincaré, for his own part, seems to have reconciled with this insurmountable obstacle:

I quite see that it might be said: We do not know, and yet we must act… We must therefore make up our minds without knowing. This must be often done whatever may happen, and we must follow the rules although we may have but little confidence in them. What I know is, not that such a thing is true, but that the best course for me is to act as if it were true. (ibid. 187)

Here we are apparently told to accept fiction and to live within it, not necessarily in denial of its shaky foundation but rather in the interest of creating an even better fiction that mimics the external universe even more, or as much a fiction possibly could. The aspirational worlds generated in fiction, the countless “invisible cities” that exist in the potentiality of creative thought, can only be occupied in this way, and so we have reached – yet again – the broad intersection of science and literature. Fiction is fiction, whether it stirs our emotions or lifts a rocket into space.

Through the inspired work of other literary researchers – in this particular case, William Goldbloom Bloch – we can be sure that Jorge Luis Borges was aware of Poincaré’s conjectures.
Having made several “end leaf notations” on his own copy of Science and Method in 1939, Borges was presumably drawn to Poincaré by way of Cantor – of whom, it has been stated, Poincaré was a detractor of the first order. (Bloch 144-45) Poincaré is not explicitly named in any of Borges’ published works; however in his 1931 essay “The Postulation of Reality” Borges delineates a narrative approach that is in some respects identical to the process of critical selection outlined by Poincaré in Science and Method.

I would recommend this hypothesis: imprecision is tolerable or plausible in literature because we almost always tend toward it in reality. The conceptual simplification of complex states is often an instantaneous operation. The very fact of perceiving, of paying attention, is selective; all attention, all focusing of our consciousness, involves a deliberate omission of what is not interesting. (SNF 61)

The “imprecision” that one finds in literature by way of authorial choice is analogous to the scientist’s approval of one formula and rejection of another, and both hearken back to an earlier citation in which Poincaré invokes aesthetic beauty, harmony and elegance as parameters for such selections. (Method 59) Whether Borges had read Poincaré by as early as 1931 or not – and of this we cannot be absolutely sure – the similarity between these two sentiments is undeniable. Curiously, Borges shares another moment of direct contact with Poincaré in a fanciful metaphor found in Science and Hypothesis: “I may be permitted to compare science to a library which must go on increasing indefinitely; the librarian has limited funds for his purchases, and he must, therefore, strain every nerve not to waste them.” (Poincaré 144) Again, the faculty of selection is stressed, and again we see a fragment of an image that Borges would come to develop – notoriously, in “The Library of Babel” – except in Poincaré’s case this flight of imagination comes with an understandably pragmatic budgetary encumbrance.

In a subsequent portion of “The Postulation of Reality” Borges, while attempting to “demolish the arguments of [Benedetto] Croce,” describes three methods of narration that also demonstrate his overarching scientific bent.
The classic postulation of reality can take three forms, which are quite diversely accessible. The easiest consists of a general notification of the important facts… The second consists of imagining a more complex reality than the one declared to the reader and describing its derivations and results… The third method, the most difficult and effective of them all, makes use of the invention of circumstances. (SNF 62-63)

By offering a precise, logical definition of what amounts to a creative and intuitive process, Borges is working very much in the vein of Poincaré’s own approach to scientific methodology, and it is no small coincidence that the three narrative approaches outlined above can be seen to correspond with “observation,” “hypothesizing” and “experimentation” – all crucial steps in the traditionally accepted scientific method.

There is, as well, a thread to be found in Calvino’s oeuvre that will lead us back to the spirit of Poincaré. Taken from an interview with Calvino in 1968, the following statements express the author’s view on the conventional nature of science:

I recently read an article by Roland Barthes called “Literature versus Science.” Barthes tends to think of literature as the awareness that language has of being language, of having a density of its own, and its own independent existence. For literature, language is never transparent, and is never merely an instrument to convey a “meaning” or a “fact” or a “thought” or a “truth”; that is, it cannot mean anything but itself. Whereas, on the other hand, the idea of language given by science is that of a neutral utensil that is used to say something else, to mean something foreign to it. This different concept of language is what distinguishes science from literature. Proceeding along these lines, Barthes gets to the point of maintaining that literature is more scientific than science, because literature knows that language is never naïve, and knows that in writing one cannot say anything extraneous to writing, or express any truth that is not a truth having to do with the art of writing… But can the science of today really be defined by such trust in an absolute code of references, or is it not in itself by this time a continual questioning of its own linguistic conventions? In his polemic against science Barthes appears to envisage a kind of science far more compact and sure of itself than it really is. (Uses of Literature 28-29)

Roughly sixty-five years after Poincaré had expressed these same doubts and explanations, we can see Calvino demonstrating a similar understanding of science’s provisional foundations. That which is said within science can only be true of science, in the same way that literature can make
no claim to demonstrate some absolute or universal truth. The mitigating factors – author, perception, method – are shared between the two disciplines, and both are understood to be founded on convention. “The scientist should no more banish [unverifiable hypotheses] than a poet banishes metaphor,” Poincaré informs his reader, “but he ought to know what they are worth.” (Hypothesis 164) There is a scientific function extant in creative literature – or at the very least in imaginative, creative thought – which is itself the driving force behind both literature and science.

In exploring this shared experience across divergent disciplines, we might briefly reconsider what has been previously discussed regarding Calvino’s ideal education – specifically, his desire for a return to interdisciplinarity and dialogue – and how this might relate to Poincaré’s own distribution of intellectual labor.

It is well that there should be logicians and that there should be intuitionists. Who would venture to say whether he would prefer that Weierstrass had never written or that there had never been a Riemann? And so we must resign ourselves to the diversity of minds, or rather we must be glad of it. (Method 120)

These two opposed strains of intellectual are not, then, in as much conflict as one might imagine; rather, they can be seen – and here we will borrow a metaphor from Guy Raffa – “not so much as two sides of the same coin as a fusion of two metals into a beautiful and useful new alloy”;¹⁴ in other words, as a set of inviolable mechanisms that contribute equally to human knowledge’s sum total. In his bluntly-titled essay “Filosofia e letteratura,” published in 1967, we find that Calvino shares Poincaré’s sentiment:

Science is faced with problems not too dissimilar from those of literature. It makes patterns of the world that are immediately called in question, it swings between the inductive and the deductive methods, and it must always be on its guard lest it mistake its own linguistic conventions for objective laws. We will not have a culture equal to the challenge until we compare against one another the

basic problematic of science, philosophy and literature, in order to call them all into question. (Uses of Literature 45-46)

In addition to recognizing the need for science and literature to interact, Calvino goes as far as mentioning again what Poincaré had taken great care to make apparent – that linguistic conventions are the sole bases of human knowledge.

Further to Poincaré’s creative methodology, which alternates periods of rigorous study with periods of idleness or distraction, Calvino makes mention of a similar process in his lecture entitled “Visibility”: “The imagination, while following channels other than those of scientific knowledge, can coexist with the latter and even assist it, indeed be a phase the scientist needs in order to formulate his hypothesis.” (Six Memos 88) The relationship between the subliminal and the conscious has already been well established in our study of Poincaré, and while it cannot be shown that Calvino necessarily learned this process directly from Poincaré, it is difficult to ignore the similarity.

In the same set of lectures written by Calvino for an intended address at Harvard University, let us also take note of the shared appreciation of economical expression and brevity across all three of the authors upon which we have set our lens. In a lecture entitled “Quickness,” we witness a collision of the sentiments of Poincaré, Calvino and Borges. Calvino declares that “writing prose should not be any different from writing poetry. In both cases it is a question of looking for the unique expression, one that is concise, concentrated and memorable.” (ibid. 49) On the very next page he lavishes praise on Jorge Luis Borges as a master of the short form. “What I particularly wish to stress is how Borges achieves his approaches to the infinite without the least congestion, in the most crystalline, sober and airy style.” (ibid. 50) We need only place these statements alongside one made by Poincaré to witness the moment of contact. “…Economy of thought, that economy of effort which… is the constant tendency of science, is a source of
beauty as well as a practical advantage.” (Method 23) Lauded by three masters of form and expression, the virtue of expressive economy captures the full breadth of the themes we have explored in relation to Poincaré. From the shared duties of the scientist and the writer of fiction in judiciously selecting only the most harmonious combinations of elements, to the mass acceptance of the shared provisional foundations that prop up the endeavors of both science and literature, and especially in tempering the role of the imagination through a constant focus on form and structure, the parallels are apparent and abundant. The universe, inscrutable in its fullness, can only be represented through language, either scientific or literary, or ideally through a fusion of both. If only the arrogant builders of Perinthia, imagined by Calvino in Invisible Cities, had known as much;

Following the astronomers’ calculations precisely, Perinthia was constructed; various peoples came to populate it; the first generation born in Perinthia began to grow within its walls; and these citizens reached the age to marry and have children. In Perinthia’s streets and square today you encounter cripples, dwarfs, hunchbacks, obese men, bearded women. But the worse cannot be seen; guttural howls are heard from cellars and lofts, where families hide children with three heads or with six legs. Perinthia’s astronomers are faced with a difficult choice. Either they must admit that all their calculations were wrong and their figures are unable to describe the heavens, or else they must reveal that the order of the gods is reflected exactly in the city of monsters. (Calvino 144-45)

**Einstein and Relativity**

The Special Theory of Relativity is arguably the most well-known scientific theory in the history of humanity, despite the fact that rather few are actually versed in its delicate nuances. The brainchild of Albert Einstein – a Swiss patent clerk and notorious daydreamer – this theory of space-time ushered a new era of science and philosophy into being. Its foundation, however, is not dissimilar to the creative impulse found at the base of any short story, dramatic novel or comedic play; “According to Einstein’s own recollection, the intellectual origin of the special
theory of relativity went back to his youth, a time when he tried to imagine what it would be like to ride along on a wave of light.” (Newton 157) Einstein’s imagination – and not his mathematical rigor or methodological steadfastness – acted as the original catalyst for this incredible idea. That a creative whim or flight of boyhood fancy would come to be the foundation for our most salient basis for understanding the universe around us is in perfect alignment with the stated purpose of our study of Calvino and Borges.

The most basic terms of the Special Theory of Relativity have been distilled by myriad scientific historians and philosophers. Roger Newton, always of great employ in our research, gives a serviceable breakdown:

If two observers in motion relative to one another see their clocks running at the same rates and their yardsticks to be of equal length, they cannot see the same light signal move at the same speed… If you are moving with respect to me, I see your clock going slow and your yardsticks contracted, and symmetry demands that you see my clock going slow and my yardsticks contracted too. The reason why this had never been noticed before and is still difficult to notice is that these effects are minute unless our relative speed is close to the speed of light. There is no universal space in which the world moves along a universal time, as [Sir Isaac] Newton had taken for granted. The standards of measurement for both space and time have to be separately established for each observer. (Newton 158)

Relativity, then, is the mathematical proof for the idea that there is no “absolute yardstick”; any claim to universality is therefore shattered, since the speed of light is fixed and limited. The transmission of information by way of light waves cannot be faster than the maximum speed of light itself;\(^{15}\) because of the yawning vastness of the universe, events occurring very far apart will not appear to happen simultaneously to any particular observer, even if in actuality they occurred at the same instant. This renders futile, then, any attempt at objective measurement based on fixed values.

\(^{15}\)“The theory also implied some important specific predictions, namely that no material body and no information can be transported faster than light and that mass and energy are equivalent, or convertible into one another, as expressed in the famous formula \(E = mc^2\), in which \(c\) is the speed of light.” (Newton 159)
There is more to this theory than simple speed limits, however – Stephen Hawking’s explication of relativity includes the crucial equivalency between speed and mass:

The fundamental postulate of the theory of relativity, as it was called, was that the laws of science should be the same for all freely moving observers, no matter what their speed… All observers should measure the same speed of light, no matter how fast they are moving. This simple idea has some remarkable consequences. Perhaps the best known are the equivalence of mass and energy, summed up in Einstein’s famous equation $E = mc^2$ (Where $E$ is energy, $m$ is mass and $c$ is the speed of light), and the law that nothing may travel faster than the speed of light… As an object approaches the speed of light, its mass rises ever more quickly, so it takes more and more energy to speed it up further. It can in fact never reach the speed of light, because by then its mass would have become infinite, and by the equivalence of mass and energy, it would have taken an infinite amount of energy to get it there. For this reason, any normal object is forever confined by the theory of relativity to move at speeds slower than the speed of light. Only light, or other waves that have no intrinsic mass, can move at the speed of light. (Hawking 20-21)

Objects with mass that are moving at the speed of light attain infinite mass, which is an obvious impossibility. Spaceships, people, and even atoms are subject to this cosmic speed limit, and cannot be propelled to the speed of light without violating the limits of relativity. Light waves, on the other hand, have no intrinsic mass and are immune to this cumbersome burden. It would not be difficult, for our purposes, to coyly extend this proviso from light waves to fiction, which also exists without mass and can only be evaluated, relatively, by a subjective observer. The lightest and least mass-laden examples of fiction would hew more closely to this rule; given Calvino’s ideal of “lightness” and the fact that, to him, Borges represented the zenith of this attribute, we can make the assumption that Borges and Calvino, in their writing, have managed to routinely unburden the world of its mass, allowing everyday objects and beings to transgress the limits dictated by relativity. Without an obligation to remain shackled to the bodily universe, Borges and Calvino’s characters and settings are able to become potential, hypothetical and

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16The ubiquitous “FTL” (“faster-than-light”) starship drives of science fiction are apparently very much trapped within the realm of fiction. - MR
wave-borne, just as Einstein wished to in that youthful daydream that moved him to create the special theory of relativity.

Aside from permitting such pleasing visual experiments, there is an even deeper philosophical significance to the theory of relativity – a notion that generates equal measures of wonder and anxiety; “Einstein’s gravitational theory represented the culmination of all of deterministic physics, and the problem that the twenty-first century inherited was to make this theory come to terms with the probabilistic revolution in physics that pervaded the nineteenth and twentieth centuries.” (Newton 166) Newton goes on to define the problem further: “When Einstein, shortly after developing the theory, began to apply it to cosmology, he found that his equations had no solutions that described a static, closed universe of fixed dimensions, with relatively slowly moving stars in it, as the cosmos was thought to be at that time.” (ibid. 169) The image of the universe as a closed system of knowable laws was suddenly incompatible with the mathematics of Einstein’s theory. Aside from overturning science’s presupposition of a causal and, more importantly, meaningful universe, this innovation also had the effect of trickling down into and muddying other fields of objective knowledge. If the hope of a firmly deterministic conclusion to the human scientific exercise was now gone, and the grand narrative of science had been reduced to a series of irresolvable conundrums relating to the reliability of subjective observers, then science itself would have to be reinvented in a new image.

While the consequences of Einsteinian relativity lend themselves readily to the study of literature and philosophy, not all scientists would agree to the legitimacy of such a comparison. Richard Feynman, an American physicist who made the fundamentals of relativity accessible to the masses by way of numerous popular science lectures and books, took issue with the malleability with which philosophers and “armchair-physicists” handled this theory.
When this idea descended upon the world, it caused a great stir among philosophers, particularly the “cocktail-party philosophers,” who say “Oh, it is very simple: Einstein’s theory says all is relative!” In fact, a surprisingly large number of philosophers, not only those found at cocktail parties (but rather than embarrass them, we shall just call them “cocktail-party philosophers”), will say, “That all is relative is a consequence of Einstein, and it has profound influences on our ideas.” In addition, they say, “It has been demonstrated in physics that phenomena depend on your frame of reference.” We hear that a great deal, but it is difficult to find out what it means. (Feynman 73)

Feynman mocks those who wield only a thematic or generalized understanding of the special theory of relativity, both for the vagueness of their explanations as well as for their gall in bandying about a concept that they have not studied deeply. There is a distinct tone of disdain in his words, with a defensive position that seems to imply that, in order for “cocktail-party philosophers” to hold their simplistic positions (unburdened by empirical proof, we should note), physicists and mathematicians have had to do all of the hard work. Our earlier discussion of C.P. Snow’s desire to merge the humanistic and scientific fields – to say nothing of Calvino’s own hope for an inclusive body of human knowledge – is met with palpable opposition in Feynman, who seems to resist the mobility of these implications of relativity outside of the borders of hard science. Feynman later deepens his argument:

“One of the consequences of relativity was the development of a philosophy which said, “You can only define what you can measure! Since it is self-evident that one cannot measure a velocity without seeing what he is measuring it relative to, therefore it is clear that there is no meaning to absolute velocity. The physicists should have realized that they can only talk about what they can measure.”” (Feynman 75)

While Feynman appears to redress the physicists for their short-sightedness in this passage, he also implicitly limits the jurisdiction of the philosopher; if only that which can be measured can be known, only those who perform such measurements carry the prestige of dictating what is known. Experiment, and not thought, according to Feynman, is the basis of knowledge.
Regardless of Feynman’s take on the cultural function of relativity, it has become an extremely popular concept in literature and art and is a defining aspect of the modern cultural paradigm. Feynman’s own words on the consequences of relativity, despite his seemingly defensive position, betray its function in affecting the basis of what can be known across all disciplines.

What, then, are the philosophic influences of the theory of relativity? If we limit ourselves to influences in the sense of what kind of new ideas and suggestions are to be made to the physicist by the principle of relativity, we could describe some of them as follows. The first discovery is, essentially, that even those ideas which have been held for a very long time and which have been very accurately verified might be wrong. It was a shocking discovery, of course, that Newton’s laws are wrong, after all the years in which they seemed to be accurate. Of course it is clear, not that the experiments were wrong, but that they were done over only a limited range of velocities, so small that the relativistic effects would not have been evident. But nevertheless, we now have a much more humble point of view of our physical laws – everything can be wrong! (Feynman 76-77)

While the physical effects of relativity can only be proven through scientific experimentation, this need not place a limit on what its implications might mean to other human activities; a statement like “everything can be wrong” does not appear to lend itself to any particular discipline, we might argue. In fact, in further support of our thesis, we can look to one final passage taken from Feynman’s lectures on relativity, this time focusing on man’s inability to even define the concept of “now”:

When we look at the star Alpha Centauri, we see it as it was four years ago; we might wonder what it is like “now”. “Now” means at the same time from our special coordinate system. We can only see Alpha Centauri by the light that has come from our past, up to four years ago, but we do not know what it is doing “now”; it will take four years before what it is doing “now” can affect us. Alpha Centauri “now” is an idea or concept of our mind; it is not something that is really definable physically at the moment, because we have to wait to observe it; we cannot even define it right “now”… There are fortune-tellers, or people who tell us they can know the future, and there are many wonderful stories about the man who suddenly discovers he has knowledge about the affective future. Well, there are lots of paradoxes produced by that because if we know something is going to happen, then we can make sure we will avoid it by doing the right thing at the
right time, and so on. But actually there is no fortune-teller who can even tell us the present! There is no one who can tell us what is really happening right now, at any reasonable distance, because that is unobservable. (Feynman 101)

Clearly offensive to all historical conceptions of time, space and the coherence of the universe, these words by Feynman do as much to validate fiction as they do to call into question the meaning of absolute truth. While scientists – burdened by requisite verification and evidentiary proof – cannot speak on “what is really happening right now,” creators of fictional works can step in and generate any number of potential “nows,” all equally valid and invalid. Their purpose is not to tell what really is, but what could be in the absence of experimental proof.

As a number of philosophers and scientists that we have already studied have noted, this fictive process can also lead to innovations in experimental science – taking an imaginative and unrestrained approach to problem-solving can introduce fresh perspectives and better angles, from which “good” scientists (if we recall Henri Poincaré’s words) can select the most constructive and proceed with further verification.

After Einstein’s Special Theory of Relativity, it was thought that much could still be known; even if the whole of human knowledge had ceased to be absolutely linear and coherent, definite facts could still be located relationally or relatively, so long as the process of measurement could be carried out rigorously and with precision. It is not a surprise, then, that what would eventually come out of Germany and Austria’s scientific communities would once again redefine the human scientific enterprise. David Lindley summarizes this development rather cleverly in his intimate portrait of this period: “Relativity doesn’t deny that there are absolute facts; that’s what the uncertainty principle does.” (Lindley 213)

Quantum Physics
The basis of quantum physics, and its namesake, is an essential unitary measurement of waves known as a *quantum*. Max Planck, widely touted as the father of quantum physics, performed a series of experiments relating to waveforms and initiated an unprecedented period of scientific creativity and frenzied experimentation. Physicist Stephen Hawking recounts that

…the German scientist Max Planck suggested in 1900 that light, X rays, and other waves could not be emitted at an arbitrary rate, but only in certain packets that he called quanta. Moreover, each quantum had a certain amount of energy that was greater the higher the frequency of the waves, so at a high enough frequency the emission of a single quantum would require more energy than was available. (Hawking 56)

In order to resolve this paradox, Planck began to employ wildly creative thinking, going so far as to incorporate seemingly-unrelated equations and matrices from diverse fields of mathematics into his calculations. In a stroke of gently-coaxed luck, one set of parameters seemed to actually work for his purposes.

In 1900, without any underlying rational justification other than strictly mathematical purposes, he applied [Ludwig] Boltzmann’s probabilistic reasoning to calculate the entropy of the energy distribution in a black body… Planck’s new radiation law turned out to agree well with experimental data. This would not be the last time in this field that imaginative scientists generated productive new theoretical ideas that appeared totally unjustified… Scientifically, Max Planck embodied the reluctant but willing transition of the old guard from classical physics to an entirely new probabilistic paradigm in which iron-clad laws changed to statistical regularities. To admit the possibility, even if rare, of a violation of the second law of thermodynamics by a fluctuation was a wrenching thought for him, and he only grudgingly accepted atoms, which, after all, were ultimately responsible for the statistical nature of thermodynamics. (Newton 212-23)

In light of this, we should recall Paul Feyerabend’s position that unfettered and imaginative rule-breaking in science can sometimes lead to major advances in knowledge, precisely when it coincides with the adoption of a pluralistic methodology and an openness to new forms of understanding. In Planck’s case, in fact (as it appears from the citation above), he indulged his creative impulse grudgingly, with an unwillingness to accept – like Albert Einstein – that there could be room for probability in the “hard” sciences.
Before moving too far into a discussion of probability, however, we will need to better define the parameters of quantum physics. Michio Kaku gives a concise primer of its main concerns:

…In quantum theory light was to be chopped up into tiny pieces. These packets of light were named photons, and they behave very much like point particles. When two electrons bump into each other, they repel each other not because of the curvature of space [itself a consequence of relativity], but because they exchange a packet of energy, the photon. The energy of these photons is measured in units of something called Planck’s constant \( h \sim 10^{-7} \text{ erg sec} \). The almost infinitesimal size of Planck’s constant means that quantum theory gives tiny corrections to Newton’s Laws. These are called quantum corrections, and can be neglected when describing our familiar, macroscopic world. That is why we can, for the most part, forget about quantum theory when describing everyday phenomena. However, when dealing with the microscopic subatomic world, these quantum corrections begin to dominate any physical process, accounting for the bizarre, counterintuitive properties of subatomic particles. ([Hyperspace](113-14))

The implications of these “quantum corrections” are even farther-reaching than those introduced by relativity. That the world we see and exist within every day might, at a microscopic level, be completely rooted in uncertainty and probabilistic randomness is nothing short of horrifying – if things do not happen because of causality or consequence, what can be known or expected in the course of a human life? There is no longer a separation between fiction and reality in quantum physics – both are exempt, at a certain level, from direct cause, and neither is governed by an immutable set of rules. It seems that Dr. Kaku may have also grappled with this thought: “If quantum theory violates our common sense, it is only because nature does not seem to care much about our common sense.” (ibid. 115) Brian Greene shares similar musings on these implications:

What business does probability have in the formulation of fundamental physics? We are accustomed to probability showing up in horse races, in coin tosses, and at the roulette table, but in these cases it merely reflects our incomplete knowledge… Quantum mechanics, on the contrary, injects the concept of probability into the universe at a far deeper level… In practice this means that if a particular experiment involving an electron is repeated over and over again in an absolutely identical manner, the same answer for, say, the measured position of an
electron will not be found over and over again… Exact outcomes of experiments cannot be predicted; the best we can do is predict the probability that any given outcome may occur. (Elegant Universe 105-107)

The distinction made by Greene is crucial – the probabilistic inconsistencies generated in quantum physics are not necessarily the results of incomplete human knowledge. Rather, it insinuates that some atomic and particulate behaviors simply do not operate according to fixed rules or, better said, that nature’s laws allow for the preeminence of randomness in such cases. The thesis of our current study only gains strength in light of such discoveries, as the border between science and fiction continues to blur and smudge.

A final step forward in our present discussion of quantum physics – and a fitting end to this chapter – can be found in the Austrian physicist Werner Heisenberg’s struggle with procuring accurate measurements of subatomic particles, the failure of which culminated in the formation of his so-called Uncertainty Principle. Stephen Hawking provides a synopsis of Heisenberg’s dilemma:

In order to predict the future position and velocity of a particle, one has to be able to measure its present position and velocity accurately. The obvious way to do this is to shine light on the particle. Some of the waves of light will be scattered by the particle and this will indicate its position. However, one will not be able to determine the position of the particle more accurately than the distance between the wave crests of light, so one needs to use light of a short wavelength in order to measure the position of the particle precisely. Now, by Planck’s quantum hypothesis, one cannot use an arbitrarily small amount of light; one has to use at least one quantum. This quantum will disturb the particle and change its velocity in a way that cannot be predicted… In other words, the more accurately you try to measure the position of the particle, the less accurately you can measure its speed, and vice versa. (Hawking 56-57)

Since there can be no smaller quantity of light than the quantum (according to Planck), and since any amount of light used to measure one or more quanta will physically affect the particles being measured, this obviously translates into a net inability to obtain accurate information about all aspects of a particle or, by extension, any one thing in toto. In the same way that focusing a lens
on an object blurs everything else within the frame, Heisenberg’s observations uncovered a blind spot in the scientific enterprise. Roger Newton’s more-detailed description of Heisenberg’s experimentation is also useful in explaining this point:

Published in 1927, it came to be known as Heisenberg’s uncertainty principle (or, more correctly translated, indeterminacy principle; he regarded it as a fundamental statement of indeterminacy at the submicroscopic level). Suppose an experiment is set up to determine the position of a particle with an accuracy $A$ and, at the same time, its momentum with an accuracy $B$; then the two error limits $A$ and $B$ cannot both be made arbitrarily small… In other words, if you want to know the position of a particle extremely accurately, making $A$ very small, then you cannot at the same time demand to know its momentum extremely accurately; the best you can achieve is $B = h/A$. Heisenberg’s conclusion from this surprising principle was that quantum mechanics could not be deterministic: in order to predict the future behavior of a particle, both its initial position and its initial momentum had to be known, but the indeterminacy principle prevented you from knowing both precisely. In fact, even to speak of a particle’s motion made little sense, since this would presuppose an exact simultaneous knowledge of both its place in space and its velocity, and such knowledge could not be obtained. (Newton 232-33)

Clearly stated: the more an observer tries to obtain information about a subatomic particle’s position in space, the less there is that can be known about its speed, and vice versa. There would always be, as Heisenberg put it, “an ‘inexactness’ (Ungenaugkeit) in the conclusions.” While obviously posing an unfortunate burden for the empirical side of science, this indeterminacy can also have a more significant and nefarious impact in the development of scientific systems.

David Lindley explains:

Heisenberg’s uncertainty nailed down the inescapability of the discord between one possible measurement and another. An observer can choose to measure this, that or the other, but has to put up with resulting incommensurabilities. And that uncertainty feeds into the future development of the system. (Lindley 154)

If the development of scientific systems can be summarized, therefore, as not much more than the exponential stacking of uncertainties over time, then the expected result should actually be a

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spiraling movement away from certainty, in which what is thought to be verifiably known rests upon ever-shakier ground. There is little space that remaining for a convincing argument on the superiority of science over fiction – almost nothing separates them at this point, with the exception of science’s burden of experimental proof. Even then, though, Heisenberg’s principle calls into question what the eyes can claim to see and what mathematical proofs can claim to substantiate. We are already, albeit unwillingly, in the fictional realm of Borges and Calvino.

Many scientists and theorists have weighed in on the deep-reaching consequences of Heisenberg’s discovery. Echoing an earlier statement by Feynman, Stephen Hawking draws out a now-familiar point:

The uncertainty principle had profound implications for the way in which we view the world. Even after more than seventy years they have not been fully appreciated by many philosophers, and are still the subject of much controversy. The uncertainty principle signaled an end to Laplace’s dream of a theory of science, a model of the universe that would be completely deterministic: one certainly cannot predict future events exactly if one cannot even measure the present state of the universe precisely! (Hawking 57)

Roger Newton, as well, speaks in fiery words of the dilemma that assails science post-Heisenberg:

The now generally accepted physical interpretation of the probabilistic laws postulated for quantum mechanics emerged in 1926 out of long discussions in Copenhagen… The Copenhagen interpretation is based on a renunciation of all assumptions of the reality of entities and processes not observable or measurable: nothing is real until it is measured. If Heisenberg’s indeterminacy principle prevents us from precisely measuring them at the same time, simultaneous position and momentum of a particle are meaningless concepts, and hence so is a particle’s motion. (Newton 242)

We should dwell for a moment on the weight of this statement – potentially, the very motion of subatomic particles is a “meaningless concept,” since it cannot be measured reliably. Where can science possibly go from here? With such a gargantuan burden of verifiable proof as the standard for scientific success, theorization had no choice but to take the place of experimentation, at least
in certain branches of physics and mathematics. “Probability thus came to be located right at the heart of quantum mechanics,” Newton explains, “a characteristic strengthened by Heisenberg’s indeterminacy principle, which made statistics into an intrinsic feature of every measurement process.” (ibid. 236)

**Cultural Function of Uncertainty**

In 2008, David Lindley commented on the nature of the towering monolith that the Uncertainty Principle had come to embody; “Heisenberg’s paradoxically precise uncertainty principle has ascended to a remarkable level of intellectual celebrity.” (Lindley 210) In the same year, the American television channel AMC launched a new dramatic series entitled *Breaking Bad*, which told the story of a high-school chemistry teacher-cum-methamphetamine cook and kingpin named Walter White. The program was exceptionally well-received, and would eventually come to be regarded as one of the finest shows in the history of television. This was surely due in part to the brilliant inclusion of a clandestine alias of White’s during the show’s later seasons, in which he is known in the underworld simply as “Heisenberg”. Perhaps no better-known pop-cultural reference to the Uncertainty Principle exists than this devious alter-ego, which re-introduced Heisenberg’s name – and, hopefully, his scientific legacy – to a wide and generally non-scientific audience.

With Walter White performing some of his most morally questionable acts under the mask of “Heisenberg,” the symbolism leads to an (admittedly obvious) meditation on moral relativism, in which the real Heisenberg’s principle, as we have already established, has moved out of the realm of physics and into the speculative world of the philosophy of “good” and “bad.” Indeterminacy does not only exist between the momentum and position of electrons – rather, it
can be found as well in human behavior, where our actions are driven by complex and conflicted motivations. “Good,” “bad,” “momentum” and “position” appear to have become interchangeable terms in the present day. David Lindley can offer more insight into this situation:

Literary deconstructionists have also made a fetish out of the uncertainty principle. They insist that a text has no absolute or intrinsic meaning but acquires meaning only through the act of being read – and therefore can acquire different meanings depending on who is doing the reading. Just as, in quantum measurements, results come about through an interaction between observer and thing observed, so too, we are invited to think, does the meaning of some piece of literature arise through interaction between reader and text (authors having evidently vanished from this equation)…Whether physicists like it or not, Heisenberg’s principle has spread far and wide and caused cultural derangement. This has nothing to do with whether quantum mechanical uncertainty has some genuine meaning in various far-flung regions of intellectual study. It has to do with the way Heisenberg has become a touchstone, a badge of authority, for a certain class of ideas and speculations. (ibid. 211-212)

This “class of ideas” is precisely what was harnessed in Breaking Bad, and in any number of other books, programs and films that philosophically consider our loss of absolute markers. Borges and Calvino are part of this grand exercise to wrangle statistical uncertainty into a reliable set of predictable beliefs or systems. Again, Lindley is a step ahead of us:

What fascinates, evidently, is the semblance of a connection, an underlying commonality, between scientific and other forms of knowledge… It tells us that scientific knowledge, like our general, informal understanding of the everyday world we inhabit, can be both rational and accidental, purposeful and contingent. Scientific truth is powerful, but not all-powerful. (ibid. 214-216)

Science, it would seem, cannot claim to be Heisenberg’s sole heir.

We might note, as we did in Feynman’s words, the critical tone toward the appropriation of the Uncertainty Principle by mass culture, or at the very least the mournful lamentation that all might be lost. There is a tendency by scientists and mathematicians to claim exclusive rights to what Heisenberg’s ideas represent, with all employment of these concepts by artists dismissed as misguided or outside of the original spirit of indeterminacy. However, Lindley reveals all that we
need to know in order to proceed with our own study without fear of misusing Heisenberg’s intellectual property. In recounting the story of Heisenberg’s first meeting with Danish physicist Niels Bohr – his friend and colleague in quantum theory – Lindley crafts an image that is as steeped in fiction as it is in fact.

He wanted to know, Heisenberg told Bohr, what quantum theory meant. Beyond the ingenious calculations and fitting of complex spectral lines to peculiar systems of quantum numbers and rules, what, he wanted to know, was the underlying conception, the true physics of it all? Bohr did not insist on the need for detailed classical models that could be translated systematically into quantum terms. Rather, he told Heisenberg, the point of models was to capture as much as one could hope to say about atoms, given the inadequacies of the ideas with which physicists were fumbling along. “When it comes to atoms,” Bohr concluded enigmatically, “language can be used only as in poetry. The poet, too, is not nearly so concerned with describing facts as with creating images and establishing mental connections.” (ibid. 86)

The fathers of quantum theory – including Heisenberg himself, who established indeterminacy as a scientific concept – approached the language of theorization as necessarily poetic and fictive; what could be said, after all, about a theory for which there was no visible proof? Bohr specifically would seem to share a special kinship with Jorge Luis Borges and Italo Calvino: “Bohr was not like other physicists. Unmathematical, he moved forward on a spiderweb of concepts, principles and riddles that, to the typical physicist, looked something like philosophy.” (ibid. 200-201) We need not rest too long upon this description of Uncertainty’s originators – perhaps it is safest to assume that for each staunch Feynman there is a poetic Bohr, and that our own interpretation of the Uncertainty Principle will be completely in line with its necessarily ambiguous message.

Before moving into the next section of our study, in which we will finally begin our deep analyses of the works of Borges and Calvino, we might best close this chapter by turning to Calvino’s perennially-neurotic subject, Mr. Palomar, and his own struggles with verifiability,
ambiguity and indeterminacy. Palomar is a complex figure, simultaneously eliciting both pathos and frustration. He attempts to regard the universe as a scientist, but remains, inescapably, a human animal, at every turn immobilized when his desire to understand scrapes against the ceiling of human cognition and reason – as always, Heisenberg’s principle in motion.

For an illustration of this hopelessly-comical cycle, we will focus on the second section of *Mr. Palomar*, specifically on a triptych entitled “Mr. Palomar in the Garden,” which finds its conclusion in a section entitled “The Infinite Lawn.” Mr. Palomar gazes at the lawn surrounding his home, regarding it first as a “uniform green expanse” and then, upon closer inspection, as actually being riddled with weeds of various species. He begins to cull his lawn, a symbolic act that may reflect man’s desire to rein the wild universe into a closed system of predictable laws and processes. But, inevitably: “When you start pulling up one weed, you immediately see another appear a bit farther on, and another, and still another.” (Calvino 30) The astute reader will recognize this scene as another possible recapitulation of the infamous paradox of Zeno of Alea, an evergreen trope in Borges’ fictions as well. Palomar attempts to resolve this quandary:

To be sure, pulling up a weed here and there solves nothing. This is how it should be done, he thinks – take a square section of the lawn, one meter by one meter, and eliminate even the slightest presence of anything but clover, darnel or dichondra. Then move on to another square. No, perhaps not: remain perhaps with the sample square. Count how many blades of grass there are, what species, how thick, how distributed. On the basis of this calculation you would arrive at a statistical knowledge of the lawn, which, once established… (ibid. 31)

Here, as with all systems of scientific inquiry based on indeterminacy, Palomar’s approach begins to spiral and grow exponentially. One never knows, he finds, at which point to stop counting blades of grass, or when a tiny sprout should be counted fully as a true “blade” of grass. “Mr. Palomar has already moved to another train of thought: is ‘the lawn’ what we see, or do we see one grass plus one grass plus one grass…? What we call ‘seeing the lawn’ is only an effect of
our coarse and slapdash senses.” (ibid. 33) There can be no system here, at least not for the impatient and sensitive Palomar. “He no longer thinks of the lawn: he thinks about the universe.”
Part 2, Chapter 1: Transfinites and Infinites

Georg Cantor

In this chapter we will begin a close analysis of the scientific themes and imagery present in the short fictions of Italo Calvino and Jorge Luis Borges. We will first focus on various representations of infinity, beginning in the early 1800s and extending into the present day. Following a brief historical contextualization of Georg Cantor, the brilliant and troubled inventor of transfinite set theory (a constant source of inspiration for Borges), we will then jump to astrophysical concepts first introduced by Albert Einstein and Stephen Hawking, and later still to the recapitulation of such concepts by modern-day physicists Michio Kaku and Brian Greene, while constantly maintaining a steady focus on what role such ideas might have played in numerous specific works by Borges and Calvino. As we progress in later chapters into more current scientific material, our close readings will intensify, until finally culminating and concluding in a discussion of science as fiction.

As the creator of transfinite set theory, Austrian mathematician Georg Ferdinand Ludwig Philipp Cantor revolutionized the logical study of continuity and the infinite. Having departed from the foundation laid by his scholarly forebears, he freely deviated from the established methodology and, often relying on scarcely more than his imagination and instinct, was at least mostly successful in establishing a new theory of numbers that would, for the first time, allow for the provisional representation of infinity as a usable mathematical value. Cantor’s specialized point sets, which resolve “discontinuities in domains of definition” (Dauben 6) (read: problems of representing the infinite or the [mathematically] irrational in patterns of numbers), came about not by following the customary logical thread of contemporary mathematics, but rather through a release from the constraints of traditional rules. As will be demonstrated in this chapter, the spirit
of this exercise is one and the same of that of liberal scientific philosophers like Paul Feyerabend, as well as those of experimental writers of fiction such as Jorge Luis Borges and Italo Calvino.

Cantor began his project from a vantage point that had already been posed by several titans of number theory and mathematics. By 1829, the German mathematician Gustav Dirichlet had established and begun to tease out the tightly knotted mass of the so-called “discontinuity problem,” a difficulty in mathematically representing infinite values; his work was continued by Georg Friedrich Bernhard Riemann. (ibid. 9) Riemann was able to narrow the focus onto the representation of discontinuous (again, “infinite”) functions and develop a brilliant but limited system which allowed for the incorporation of isolated infinities within specific formulas. According to Joseph Dauben, a Cantor biographer and historian, this meant that Riemann had “focused only on the sum function” (ibid. 13) – or, more clearly, that the methodology of reaching a sum became irrelevant so long as, in the end, the correct sum was attained. Just as Paul Feyerabend would implore of his eventual contemporaries, Riemann innovated by spackling shut the peepholes in the wall of mathematics that stubbornly suggested the endless, unapproachable abyss that lay behind. Necessarily, these provisional solutions only proved useful for very specific functions, cases and conditions, but they worked better than any idea had worked before. His master stroke, the introduction of the “auxiliary function” – denoted $F(x)$ – brought about a total shift in perspective as the first systematic treatment of discontinuous functions, and would come to inspire yet another generation of revolutionary mathematicians. (ibid. 15-18)

In the late 1800’s, German mathematician Hermann Hankel, drawing from Riemann’s discoveries and working concurrently with him, succeeded in multiplying arithmetical
singularities (basically zero-value variables) by transplanting them into other algebraic functions. Simply stated, this allowed a potentially infinite number of singularities to be found within any finite interval – for example, the space between 0.1 and 1.0. The magnitude of this innovation might be easily overlooked, so better to pose it in sharper terms: for the first time in history, a mathematician was able to actually contain and resolve a singularity inside of a rational set of values – in essence, to hold a “condensation of infinities” in the palm of his hand. (ibid. 24) The philosophical implications of this were – and are – understandably staggering; incidentally, Borges famously toyed with the implications of this age-old quandary in an essay entitled “Zeno’s Paradox.”

Infinity is not only represented in Hankel’s functions, it is also used and manipulated. In 1870, in his doctoral thesis defended at Tübingen University, he posited that, in the same way that problems of division had required the introduction into the mathematical lexicon of rational numbers – not to mention similar issues with quadratic problems requiring the subsequent invention of irrational and complex numbers – so was a novel number system needed here to resolve the limitations of representing the discontinuous and the infinite. The existing mathematical language, to put it bluntly, wasn’t cutting it. Hankel’s justification, cited from his Universitätsprogramm, is strangely moving:

Actual proof of the existence of functions of the most illegitimate kind… has been necessary to show beyond a doubt that the legitimacy of functions does not come to us arbitrarily dictated from some mysterious, inflexible necessity which lies in the “Nature of Things” as one often hears, but is rather a wise, convenient and conventional limitation which we impose on ourselves. (ibid. 26)

Here, though, the notion of the singularity has just barely been touched. Through the efforts of Dirichlet, Riemann and Hankel, the stage had been set for the emotionally troubled and

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mystically-minded Georg Cantor to overthrow the very concept of “real numbers” and introduce transfinite set theory to a shocked world of mathematicians, logicians and eventually writers of fiction.

Georg Cantor’s first scandalous gesture was in his re-elaboration and expansion of Riemann’s $F(x)$ function, through which, we may recall, he managed to squeeze a theoretical infinity of unique points into a given space by permitting numerous exceptions to traditional methods of representation. (ibid. 34) These exceptions fomented an immediate backlash among his colleagues and superiors – they were uneasy with his apparent eagerness to abandon the established methodology in order to make his functions valid. In 1871, Cantor took a cue from Hermann Hankel and began to merge singularities into his work as well, hoping to extend the usefulness of his functions past finite numbers and exceptional points. (ibid. 36) Here, though, a monolithic problem arose: with multiple layers of tangled singularities to work with, Cantor found himself at a disadvantage when using the traditional number system of mathematics, as it did not lend itself readily to the work that he was attempting to do. Like the indiscrete, continuous sections of Palomar’s “infinite lawn” that we have seen in Calvino’s Mr. Palomar,\(^{19}\) it was impossible to tell at which point one singularity ended and another began, or to designate the order in which they were situated. In order to move forward, he decided – rather impetuously – to build his own number system from the ground up, in which there would be no presupposition of the existence of irrational numbers (ibid. 37); simply stated, his number system would allow the irrational to remain rational from the very start. As Dauben notes, “Cantor had devised a scheme whereby it was possible to identify with precision and rigor complicated

\(^{19}\)“A lawn does not have boundaries; there is a border where the grass stops growing, but still a few scattered blades sprout farther on, then a thick green clod, then a sparser stretch: are they still part of the lawn, or not? Elsewhere the underbrush enters the lawn: you cannot tell what is lawn and what is bush. But even when there is nothing but grass, you never know at what point you can stop counting: between one little plant and the next there is always a tiny sprouting leaf that barely emerges from the earth…” (Calvino 31-32)
configurations of points distributed in certain specified ways on the geometric continuum.” (ibid. 40)

As all of this theorizing was necessarily arbitrary, Cantor contented himself by establishing point sets that simply represented “neighborhoods” of points rather than individual points – this technically allowed statistical precision without having to resolve the impossible issue of locating each potential singularity. He simply named a point set $P'$ when it contained an individual point $P$. If the points within $P'$ were theoretically infinite, a higher order set of $P''$ could be generated to contain it. This ordering of sets, like an endlessly dense Matryoshka doll, could potentially go on forever ($P^{(\infty +1)}$), but like each individual doll the structural properties of these point sets could be neatly identified. Cantor had found a way for mathematicians to wield infinity.

As years passed for Cantor, he worked feverishly to legitimize these theories to his peers and the mathematical world at large. Wracked by self-doubt and anxiety and prone to nervous breakdowns and violent outbursts, he delusionally characterized his creation of transfinite sets as being “divinely inspired,” (ibid. 285-291) which no doubt increased the pressure that he felt to complete his work, and presumably also magnified the caustic skepticism that others harbored toward his strange ideas. These dialectically-generated numbers were, for him, non-arbitrary and undeniably real. (ibid. 82) For his colleagues, though, his use of the infinite as a “completed” idea was not only mathematically inconsistent but potentially dangerous.

Cantor responded to this criticism with a redefinition of the rules of transfinite set theory, foremost of which was his proclamation that it was simply incorrect to assume that infinities demonstrated the same arithmetical characteristics as finite numbers – they were necessarily different, of a completely separate order of existence, and could not be productively compared to
finite numbers. In fact, being infinite, these numbers should absolutely not be thought of as exhibiting finite properties at all. This argument, of course, was airtight within the parameters of Cantor’s own system, but those still living in the world of traditional mathematics were nonetheless inflamed and befuddled. Cantor had shattered the old concept of the infinite as an “untouchable” concept, (ibid. 124) and had even introduced a vague but notable distinction between actual and potential infinities. He appealed to his contemporaries with the same fire that would be seen in the likes of Thomas Kuhn and Paul Feyerabend, extolling the “freedom of mathematics to accept the creation and application of new ideas solely on the grounds of intellectual consistency.” (ibid. 132) By putting imagination and creativity first, Cantor claimed that set theory’s “application to physical phenomena of the external world was of considerable but subsidiary importance,” (ibid. 133) a claim with which both Borges and Calvino, as writers of fiction and lovers of imaginative experimentation, would probably agree.

Cantor’s introduction of the Hebrew symbol $\aleph$ – pronounced “aleph” – into his equations was perhaps his final major innovation in legitimizing transfinite set theory, and its mystical, Kabbalistic undertones imbued that which he already considered to be a “divine” concept with even more arcane weight and depth. Meant to represent the first transfinite cardinal number (which, in turn, would represent the power of the set of all finite cardinals), $\aleph$ cannot be a finite number, as it is larger than all finites. (ibid. 181) Essentially, the aleph is a symbolic representation of an infinite unity, or a singularity – a figurative black hole. Cantor was able to establish this unity through his statements $\aleph_0 + 1 = \aleph_0$ and $\aleph_0 \times \aleph_0 = \aleph_0$; the $\aleph$ exhibits characteristics that are unique to infinities, as is shown by its obliteration of the value of 1 in the first example and its resistance to being multiplied in the second.
This was to be Cantor’s big moment – the apotheosis of transfinite set theory as a coherent and transcendent mathematical system. Sadly, although perhaps not unexpectedly, his further proofs were disappointingly incomplete. One major stumbling block became his inability to prove the comparability and sequential order of alephs. (ibid. 195) The entire enterprise seemed anticlimactic if one transfinite cardinal could not be distinguished from another, or if they could not be put into some sort of hierarchical order. An even more damning flaw was the horrifying logic of the “set of all sets” (ibid. 242) – if a transfinite “master” set could theoretically contain all other transfinite sets but not itself, it must itself belong to yet another higher-order set. However, since this set also had to be a member of the master set, the inevitable conclusion was an irresolvable paradox: either a lower-order set contained a higher-order set, or a set contained itself. Italo Calvino would later come to dub this, “the paradox of an infinite whole that contains all other infinite wholes,” as “the undecidable”; the inexorable vortex of infinity had begun to pull transfinite set theory down into an endless regress. Like Calvino’s Palomar in the “Invasion of Starlings,” who, when confronted with the task of delineating the borders of a constantly shifting and churning flock of birds, falls under the spell of “a vertigo that [gripped] him at the pit of the stomach” (Calvino 63); Palomar, like Cantor, is overwhelmed by the smudged and disobedient borders of the limitless.

None of Cantor’s conclusions satisfied anyone, least of all himself. The French mathematician Henri Poincaré famously took up arms against Cantor’s proofs, calling transfinite numbers a “disease” of which mathematics could eventually and hopefully be cured. He went on to accuse Cantor of employing “contradictory and meaningless concepts” that would cause mathematics to become a “complex system of tautologies.” (Dauben 266) Other mathematicians railed against what they saw as Cantor’s introduction of psychologism into mathematics. Cantor

was heartbroken at his own inability to defend his theory against such attacks, despite having virtually scraped against the ceiling of what was knowable to mankind. He believed deeply in his theory, and did not see the paradoxes in his system as being anything other than totally coherent manifestations of the Absolute, or “the virtual word of God.” (ibid. 248) Dauben explains that:

The set of all transfinite numbers, like the absolute itself, could be acknowledged but it could never be completely understood… The mystical-religious implications were all a part of Cantor’s conceptualization of the infinite… He always regarded the absolutely infinite succession of transfinite numbers as a thoroughly appropriate symbol for the absolute. (ibid. 245)

The sharpest details of Cantor’s set theory remain unproven today; the lacunae found therein do not lend themselves willingly to proofs, although many have tried. In a study of literature as science (and vice-versa), however, this lack of proof need not be overly disconcerting – as Borges and Calvino have shown us, the potentiality of an idea can be worth much more than its scientific viability.

To begin a study of Borges’ employment of ideas from Cantorian set theory, it will be appropriate to first introduce a short piece that demonstrates Borges’ awareness of the subject: his 1940 book review of Mathematics and the Imagination by Edward Kasner and James Newman. Always wry, Borges tells the reader that “its four hundred pages lucidly record the immediate and accessible charms of mathematics, those which even a mere man of letters can understand, or imagine he understands,” including even “the rudiments of the theory of transfinite numbers.” (CNF 249) Here, Borges is winking at us – he is much more familiar with this concept than he lets on. Four years earlier, in 1936, he had published an essay entitled “The Doctrine of Cycles,” which harnessed Cantorian methodology to present a possible refutation of Friedrich Nietzsche’s doctrine of the “Eternal Return.” Briefly summarized, it posited that Nietzsche had been credited with presenting the idea that, in a universe in which there exist a
finite number of atoms coupled with infinite time, all possible permutations of the universe must eventually come into being. Over an infinite time period, all variations and combinations will necessarily repeat themselves (even down to our own births and deaths!), the universe having exhausted all possible novel forms and interactions. This should, theoretically, continue *ad infinitum*. Borges readily admits to his self-doubt in presenting a refutation to this idea. After latching onto a quote by Nietszche from *Thus Spake Zarathustra* – “I never denied that the vicissitudes of matter were copious; I said only that they were not infinite” (ibid. 116) – Borges is obliged “to fall back on Georg Cantor and his heroic theory of sets.”

“Cantor destroys the foundation of Nietszche’s hypothesis,” Borges tells us. “He asserts the perfect unity of the number of points in the universe, and even in one meter of the universe, or a fraction of that meter.” (ibid. 116) An infinitude of derivable points in finite space, to Borges, is the equivalent of an infinity of matter. He demonstrates this using a tableau from set theory in which the sets of all even or odd numbers are shown to be just as infinite as the set of all numbers. Borges’ grasp on Cantor’s ideas is evident here, with this infinite series of all numbers being broken down into equally infinite (but structurally diverse and distinct) subsets. Borges provides several other examples of the infinity of physical points in the universe, and concludes the section by stating that “if the universe consists of an infinite number of terms, it is rigorously capable of an infinite number of combinations – and the need for a Recurrence is done away with. There remains its mere possibility, which can be calculated as zero.” (ibid. 117)

While potentially his most explicit discussion of Cantorian set theory, this refutation of Nietszche was not necessarily Borges’ first. An aforementioned essay published in 1929 (when Borges was thirty years old) entitled “The Perpetual Race of Achilles and the Tortoise” recapitulated the ancient riddle of the Greek philosopher Zeno of Elea, which details a race
between Achilles and a tortoise, and in which the tortoise has graciously been given a ten-meter head-start by the tenfold-faster Achilles. Demonstrating comparative gains in space, the race continues without end as the space between the two contestants approaches (but does not ever reach) zero. With each subsequent subdivision of space, Achilles edges ever closer without ever overtaking the tortoise, due to the increasingly smaller spatial subdivisions that continually splay out before them. Zeno’s conundrum, to Borges, is a potentially harrowing thought experiment involving the same infinite divisibility of space that would come to be seen explicitly in the “Doctrine of Cycles.”

Borges vivisects Zeno’s paradox in the following way: “We can divide ten units by ten, and the quotient again by ten, as many times as we want, and [the] subdivisions of the time in which it all occurs. But an unlimited number of subdivisions can occur within what is limited.” (ibid. 44) Borges also invokes another notable name in scientific philosophy, Henri Bergson, who famously championed the idea of the non-discrete nature of time, and the inability of science and mathematics to adapt to its continuous and non-segmented nature – specifically, Borges argues that Achilles’ movements across time could not be segmented in the same way as the space that he crossed, and as such Zeno’s paradox was simply inapt.21 To reinforce this point, Borges employs the aforementioned tableaux delineating the infinite subsets of even and odd numbers contained within the group of all numbers in order to illustrate, once again, that “the part… is no less copious than the whole.” (ibid. 46) Borges finally grants us a diplomatic conclusion: “Zeno is incontestable, unless we admit the ideality of space and time. If we accept idealism, if we accept the concrete growth of the perceived, then we shall elude the mise an abîme of the paradox.” (ibid. 47)

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Curiously, much of this essay is identical to the text of “The Doctrine of Cycles,” with the notable absence of any mention of Georg Cantor, transfinites or even set theory. This would suggest that Borges recycled segments of this essay once he had later found suitable mathematical inspiration in Cantor, a supposition that lends credence to his (and our) assertion that scientific concepts can indeed inform and drive the creative forces of literature.

There is no better emblem of the concept of Cantor’s aleph in Borges’ oeuvre than what can be found in the eponymous tale “The Aleph.” So enchanted must Borges have been by the mathematical, spiritual and occult potential of this aspect of the infinite that he seems to have made it the focal point of what many consider to be his greatest work of short fiction, written some twenty years after his exposition on Zeno’s paradox. “The Aleph” details the Borgesian narrator’s loss of the object of his longstanding affection, the overwhelmingly beautiful – and recently deceased – Beatriz Viterbo. Over the course of several years following her death, the narrator, uninvited, returns to her home every April 30th to attend a memorial dinner, gradually becoming familiar with her first cousin, the decadent poet and arrogant blowhard Carlos Daneri – as Borges describes him, “authoritarian, though also ineffectual.” (ibid. 275) Daneri’s poetic mission is to “versify the entire planet,” (ibid. 277) through a pompous and labyrinthine long-form work entitled “The Earth,” which was, according to the narrator, “a poem that seemed to draw out to infinity the possibilities of cacophony and chaos.” (ibid. 280) As the narrator spends increasingly insufferable evenings in Daneri’s company, it is eventually revealed that the inspiration for Daneri’s poem – and the font of his arcane and esoteric imagery – is an “Aleph,” found “in one corner of the cellar.” (ibid. 280) An Aleph, our narrator explains, “is one of the points in space that contain all points”; more specifically, it is “the place where, without admixture or confusion, all the places of the world, seen from every angle, coexist.” (ibid. 281)
One need simply lie down in complete darkness on the cellar’s tile floor, focus one’s eyes on the space below the nineteenth step of the stairway, and wait. Borges’ narrator obliges, but also assumes, of course, that Daneri has lost his mind, and fears that he has unwittingly become the prisoner of a madman in that obscure cantina. Amazingly enough, within moments, the narrator encounters precisely the same stupefying phenomenon that was described by Daneri.

Of particular interest at this point in our analysis is the language that Borges employs in discussing his narrator’s crisis of description – much as Georg Cantor’s transfinite numbers failed to provide solace from the insuperable problem of representing the infinite, so does Borges’ narrator struggle to find a similar technique to “show” us the Aleph in this story.

I come now to the ineffable center of my tale; it is here that a writer’s hopelessness begins. Every language is an alphabet of symbols the employment of which assumes a past shared by its interlocutors. How can one transmit to others the infinite Aleph, which my timorous memory can scarcely contain? …And besides, the central problem – the enumeration, even partial enumeration, of infinity – is irresolvable. (ibid. 282)

This citation presents a serviceable-but-tenuous link to Cantor’s theories, but thankfully Borges provides an even more explicit connection in the postscript to “The Aleph.”

‘Aleph,’ as we all know, is the name of the first letter of the alphabet of the sacred language. Its application to the disk of my tale would not appear to be accidental. In the Kabbala, that letter signifies the En Soph, the pure and unlimited godhead; it has also been said that its shape is that of a man pointing to the sky and the earth, to indicate that the lower world is a map and mirror of the higher. For the Mengenlehre, the aleph is the symbol of the transfinite numbers, in which the whole is not greater than any of its parts. (ibid. 285)

This directly-stated parallel with Georg Cantor is perfectly in line with what we already know of Borges’ interest in and awareness of Cantor and transfinite set theory. We can see echoed in Borges’ attempt to ascribe discrete physical features to an object that suggests the discontinuous the very same approach that Cantor employed in his toil to qualify and sketch transfinite sets,
which are also figures or images that are meant to somehow contain the totality of existence within finite space.

Borges’ postscript to “The Aleph” leaves his reader spiraling in exactly the same feedback loop that plagued Cantor’s final proofs of transfinite set theory – namely, the difficulty of establishing the comparability and sequentiality of distinct transfinite alephs, along with the final paradox of the set of all sets, which cannot contain itself, and therefore cannot possibly be the final set in the transfinite hierarchy despite containing all other sets. Our narrator says:

I would like to know: Did Carlos Argentino [Daneri] choose that name, or did he read it, applied to another point at which all points converge, in one of the innumerable texts revealed to him by the Aleph in his house? Incredible as it may seem, I believe that there is (or was) another Aleph; I believe that the Aleph of Calle Garay was a false Aleph.” (ibid. 285)

Borges then names several other legendary artifacts that, throughout history, have been suspected of possessing the ability to reflect or display infinity to those who regarded them. In citing these other possible Alephs, all of which display the characteristics of a “final” Aleph or “set of all sets,” Borges gives us an exact mapping of the upper echelons of Cantor’s transfinite structure. These number sets/ infinity proxies all refer to one another (by way of referring to infinity) but cannot necessarily be hierarchically ordered – there is no way for us to tell which is the “real” final Aleph and which are simply the “false” ones that point toward the master set. This is precisely the conundrum that stumped Cantor, re-elaborated in the form of creative fiction.

“Does that Aleph exist…?” asks our narrator. This is unfortunately not a rhetorical question. We can safely assume that Borges is content to end his study with this replication of Cantor’s problematic continuum hypothesis. In any event, we still do not possess a solution to this paradox, despite the best efforts of Cantor and Borges, and almost one-hundred additional years of mathematical advancement.
In keeping with the theme of Borges’ portrayal of objects that tend toward or represent infinity, we will now focus on “The Zahir,” another story in the collection entitled *The Aleph*. In this tale we are told that, currently, the Zahir is a “common twenty-centavo coin into which a razor or letter opener has scratched the letters N T and the number 2.” (ibid. 243) At various moments in history, the narrator informs us, the same Zahir has nevertheless also existed as a tiger, a blind man, an astrolabe, a compass, a vein in the marble of a pillar and, poetically, the bottom of a certain well. We are told that this coin-Zahir has come into the possession of Borges’ narrator following the death of a beloved Argentine film and magazine star, Teodelina Villar. We should note immediately the similarities between this premise and that of “The Aleph” – clearly Borges is presenting us with another variation on a theme, only this time it is a movable singularity rather than the fixed maw of Carlo Daneri’s enchanting, subterranean Aleph.

Following Villar’s wake, the narrator is unknowingly given the Zahir as part of his change for the purchase of a *caña de naranja*, or brandy and orange juice, at a café, presumably as he attempts to console himself over the loss of the woman that he had so adored from afar. Seemingly magnifying the implied potentiality of the Zahir’s infinitude, three men in the café are playing *truco* during Borges’ transaction. *Truco*, as Andrew Hurley explains in the notes to Borges’ *Collected Fictions*, is “a card game indigenous, apparently, to Argentina. Borges,” he continues, “was fascinated by this game… *Truco*’s nature, for JLB, is that combination of fate and chance that seems to rule over human life as well as over games: an infinitude of possibilities within a limited number of cards…” (ibid. 541) *Truco* not only involves complex rules and intricate strategies, but is also heavily reliant on deception, confusion and feigned misunderstanding.²² That the Zahir be transmitted to Borges’ unreliable narrator (a potentially beguiling artifice in and of himself) while this symbolic representation of maddening infinity

plays out in the background is nearly perfect in its effect, and again illustrates Borges’ acute contextual awareness.

The actual experience of beholding the Zahir is where the reader will note a sharp deviation from the formula of “The Aleph.” Rather than representing an actually infinite visible experience that occurs extra-corporeally, the Zahir seems to instead suggest a potential infinity (we will surely recall Cantor’s “potential infinities” at this point), which then triggers a semiotic avalanche – A refers to B, B to C and so on, in quick succession and with overwhelming simultaneity. Our narrator describes his first such experience:

I looked at it for an instant, then walked outside into the street, perhaps with the beginnings of a fever. The thought struck me that there is no coin that is not the symbol of all the coins that shine endlessly down throughout history and fable… Possessed, without a trace of sleepiness, almost happy, I reflected that there is nothing less material than money, since any coin (a twenty-centavo piece, for instance) is, in truth, a panoply of all possible futures… (I had no suspicion at the time that these “thoughts” were an artifice against the Zahir and a first manifestation of its demonic influence.)… The next day I decided I’d been drunk. (ibid. 245-6)

Our narrator is assailed by the palpable, tangible existence of all coins when confronted with the Zahir. In order to escape the vertigo that this induces, he “loses” the coin in a randomly selected café far from his home, as payment for another brandy.

Time passes, but the narrator is unable to purge himself of the memory of his encounter with the Zahir. “It was futile to tell myself that that abominable nickel disk was no different from the infinite other identical, inoffensive disks that pass from hand to hand every day.” (ibid. 246)

He passes sleepless nights until he encounters, miraculously, a book on the phenomenon of the Zahir, “Urkunden zur Geschichte der Zahirsage (Breslau, 1899).” He learns that zahir, in Arabic, “means visible, manifest, evident; in that sense, it is one of the ninety-nine names of God.” (ibid. 246) Again, we find ourselves in an apt position to return, briefly, to Georg Cantor’s Alephs –
functionally identical to the zahir, they are the visual or “physical” manifestation not of the infinite itself, but of the suggestion of the infinite. One Aleph, in its unprovable sequentiability or cardinality, necessarily evokes all others; none of these, however, is larger or smaller than any other, regardless of whether it is denoted $\aleph_0$, $\aleph_1$ or even $\aleph_\omega$. This same equivalence is shared between the tiger-Zahir, the blind-man-Zahir and the marble-vein-Zahir, as well as all others; like Cantor’s Alephs, they are all mere arrows pointing to the one Absolute infinity – Cantors’ God – which cannot be represented, perceived or even imagined. Borges’ Aleph, on the other hand, seems to be an attempted representation of the Absolute itself, which of course must fail due to the limitations of human language and understanding.

In the end, the narrator of “The Zahir” is unable to forget his harrowing encounter with the abyss. We are told, in fact, that others in town have also beheld the Zahir, and it has led to their incarceration in a home for the mentally disturbed. (ibid. 248) Borges’ speaker resigns himself to what seems to be his only possible future – the anonymous plenitude of the Zahir.

Time, which softens recollections, only makes the memory of the Zahir all the sharper. First I could see the face of it, then the reverse; now I can see both sides at once… It is as though the vision were itself spherical, with the Zahir rampant in the center… Anything that is not the Zahir comes to me as though through a filter, and from a distance. (ibid. 248)

He concludes with a statement that is utterly evocative of our previous interpretation of Cantor’s Absolute: “Perhaps behind the coin is God.” (ibid. 249) God is not the coin itself, then, after all – like all other transfinites, the coin simply refers to Him, infinitely.

Borges attempts another permutation of the transfinite in “The Writing of the God,” the story of a Mayan priest who has been imprisoned by the Spanish in a deep, lightless well. He shares this prison with a jaguar, and is separated from the beast by a very tall dividing wall with a metal grate at the bottom. Most of the time they dwell in complete darkness, but once a day they are given food and water, and Tzinacán, the priest, can briefly make out the jaguar’s
features in the fleeting daylight. To pass the time until his inevitable execution, Tzinacán attempts to remember all that he has seen and known in his entire life. This exercise leads him to recall the legend of a “secret text” written by the god Qaholom in an unknown place, which would provide the power not only to free Tzinacán from his prison but also to bring on the end of days.

Tzinacán languishes until he recalls that one of the names for Qaholom is tigre – the Spanish word for the jaguar. (ibid. 251) At this thought, Tzinacán is “filled with holiness” – the text must be written on the flesh of the jaguar, he decides. From this point on, Borges’ narration becomes that of Tzinacán’s struggle with the essentially transfinite nature of deciphering a god’s language.

What sort of sentence, I asked myself, would be constructed by an absolute mind? I reflected that even in the languages of humans there is no proposition that does not imply the entire universe… I reflected that in the language of a god every word would speak that infinite concatenation of events, and not implicitly but explicitly, and not linearly but instantaneously… A god, I reflected, must speak but a single word, and in that word there must be absolute plenitude. No word uttered by a god could be less than the universe, or briefer than the sum of time. (ibid. 252)

Soon after this observation, Tzinacán experiences a dream in which his portion of the well is gradually filled by multiplying grains of sand. Mid-dream, he realizes that he is dreaming and hears a voice say, “You have wakened not out of sleep, but into a prior dream, and that dream lies within another, and so on, to infinity, which is the number of grains of sand. The path you are to take is endless…” (ibid. 252) Borges, here, manages to posit the same idea swathed in two layers of imagery: the infinitely-many denote the One, and the One is infinite.

Perhaps nowhere else in his oeuvre does Borges enjoy such free usage of the term “infinite” – it appears four times in just two pages, not including the synonyms “endless” and “absolute.” His overarching goal in “The Writing of the God” appears to be that of delineating
the gulf between the human and the divine/absolute (he seems to deliberately make no distinction between these terms), as well as exploring the idea of exterior infinity as a mirror of, or source for, the interior, finite multiplicity of the mortal world. As Tzinacán, either ecstatic or delusional, finally receives the omniscient vision that provides him with Qaholom’s secret phrase (fourteen words, “apparently random”), his cares for the world dissolve and he, “lying in darkness,” simply allows the days to forget him. (ibid. 254) Tzinacán, it would seem, has achieved what Cantor could not, and has transcended the fetters of the rational. In an essentially Buddhist turn, he has joined the irrational, the discontinuous… or, for lack of a better word, the *infinite*.

Before turning our attention to several appearances of the transfinite in Calvino’s works, we must light upon one additional Borges novella – “The Book of Sand,” published in 1975, a full twenty-six years after the stories in *The Aleph*. This story speaks of a book of infinite pages, offered for sale by a traveling bible salesman who, in turn, first encountered it in India; it is bartered for and purchased by our curious narrator for the price of one rare bible and the entire sum of his pension. While this particular story is uncharacteristically short on plot, in typical Borgesian fashion the attributes of this “infinite” book are extremely dense and warrant attentive study.

The narrator’s initial perusal of the book yields the following description:

The characters were unfamiliar to me… At the upper corner of each page were Arabic numerals. I was struck by an odd fact: the even-numbered page would carry the number 40,514, let us say, while the odd-numbered page that followed it would be 999. I turned the page; the next page bore an eight-digit number. (ibid. 481)

The book, as a set that contains infinite numbered units, represents yet another example of a Cantorian transfinite set. As such, it also contains the same continuum fallacy with which Cantor struggled so desperately. The book salesman provides more details: “The number of pages in this
book is literally infinite. No page is the first page; no page is the last. I don’t know why they’re numbered in this arbitrary way, but perhaps it’s to give one to understand the terms of an infinite series can be numbered any way whatever.” (ibid. 482) Borges’ deep familiarity with Cantor is demonstrated through this quotation, and his astonished narrator’s befuddlement could even be seen as a lighthearted caricature of the effort – and madness – required in contemplating Cantorian set theory.

The narrator examines the book; he chooses a page, then closes the book and attempts to find the same page again. He is unable – the pages multiply under his fingertips. He is likewise unsuccessful in reaching the first and last pages of the book, as, somehow, ever more pages of unfamiliar script seem to spontaneously generate before he can reach the binding. “I went to bed but could not sleep… I took out the impossible book and turned its pages… there was a number in the corner of [a] page – I don’t remember now what it was – raised to the ninth power. ” (ibid. 483) Pages continue to multiply and confound. Finally, an exhausted, harried and terrified narrator, wracked by a growing obsession with the book and haunted by tortured dreams, decides to (as with the Zahir) “lose” the book in the National Library, choosing a shelf upon which to abandon it at random and never again entering the library or even walking along the same street where it is found.

“The Book of Sand” presents a number of challenges for the reader and the mathematician alike. For the reader, the ability to visualize an infinite book – really intending “visualize,” not only “imagine” – is a colossal effort, as no person has ever seen anything like it, nor have they seen infinity. For the mathematician, the problems are more concrete; aside from the aforementioned crisis of transfinite continuity, there is also the matter of the physical size of an infinite book. Our first assumption might be that an infinite book should be infinitely large,
and therefore should take up all of the space in the universe, but luckily Borges gives us a
different parameter to work with. It can be held in the hands, and though it does have an
“unusual heft,” (ibid. 481) it apparently does not weigh an infinite amount. William Goldbloom
Bloch, one of few scholars to write on the mathematics of Jorge Luis Borges, hypothesizes quite
astutely that, in order for an infinite number of pages to fit within a book that has, more or less,
the same physical characteristics of other books, the infinite pages within it must be “infinitely
thin.” (Bloch 51). A book full of infinite, infinitely thin pages, Bloch tells us, must then be
visualized as being infinitely thin itself – having “measure 0,” or zero thickness, in other words.
Bloch’s complex mathematical interpretation highlights Borges’ departure from the laws of
physical reality – whether this is due to a misunderstanding or miscalculation, or simply to the
great author’s desire to exercise poetic license, is unfortunately not for us to say.

Borges may have considered this possibility, though, judging by the aborted introduction
that he provides for this novella: “The line consists of an infinite number of points; the plane, of
an infinite number of lines; the volume, of an infinite number of planes; the hypervolume, of an
infinite number of volumes… No – this, more geometrico, is decidedly not the best way to begin
my tale.” (CF 480) Considering that the infinite book may very well be summarized as a volume
consisting of an infinite number of flat planes, we may be inclined, then, to take these statements
as examples of typically understated Borgesian irony. In this further recapitulation of Zeno’s
paradox Borges has shown us another Aleph, another specular manifestation of infinity, and
another brief, chilling moment of contact with the uncountable.

Kurt Gödel
Kurt Gödel, the Austrian-American logician whose so-called “Incompleteness Theorem” called into question the internal consistency of all logical and mathematical systems, was, as we have noted, part of the army of scientists and thinkers who reacted to Georg Cantor’s theories with understandable doubt and confusion. But unlike Cantor’s more venomous opponents, Gödel responded not with *ad hominem* attacks on Cantor’s tendency toward psychologism and metaphysics, but instead with an assault on the very foundation of all knowledge, simultaneously undermining Cantor’s suppositions and those of all other mathematicians.

In the wake of Cantor’s novel number system and the concurrent advent of new approaches to arithmetic, the mathematical arena was coming to be recognized as being much more abstract and formal than had been traditionally supposed; in a sense, math was becoming more like the arts, including literature. (Hofstadter 10) A new creative freedom was in the air – perhaps embodying the same eventual spirit of Paul Feyerabend, if not yet of the same magnitude. This intensified formalization of math emancipated thinkers’ minds from the restrictions of customary interpretations of functional expressions – there were new algebras, new geometries, and broader uses for both. But this freedom brought with it a commensurate cost: how could we show the consistency of postulates that are not true of the “space of ordinary existence”? (ibid. 14) Mathematicians circumvented this problem by converting each postulate into a true statement or theorem about the model with which they were working, thereby creating a tiered system of axioms that reflected the accepted truths of a specific system.

It is in precisely this area that Kurt Gödel focused his incisive critique; this axiomatic specularity did not *solve* the problem of internal inconsistency, he stated, but instead simply shifted any given problem to another domain, where it nevertheless remained logically incomplete. (ibid. 17-19) His argument hinged on the possibility that, “even if all observed facts
are in agreement with the axioms… a hitherto unobserved fact may contradict them and so 
destroy their title to universality. Inductive considerations,” he continued, “can show no more 
than that the axioms are plausible or probably true.” This supposition is readily extended from 
the specific (the *Principia Mathematica*, in Gödel’s original case) to all logical systems. Here, 
then, is Gödel’s great achievement – laying bare the endless referential drift that is necessarily a 
part of all finite, human systems. That all proofs derived from axiomatic systems are beholden to 
the assumed consistency of yet another system (and so on, un-ironically *ad infinitum*) does not 
provide any “absolute” proof of anything – indeed, the most elegantly conceived human system 
can only ever be provisional *at best*. (ibid. 19-20) Our inability to see behind the tapestry of 
finitude prevents us from ever conclusively verifying the solidness of anything that we create as 
human beings.

At this point, Gödel’s connection to Cantor is clear enough – the latter’s struggle to 
uncover a hidden, universal transfinite code was valiant and ingenious but ultimately futile. 
What, if any, were the effects of this idea on Italo Calvino and Jorge Luis Borges? What might 
they have gleaned from a statement such as “the vast continent of arithmetical truth cannot be 
brought into systematic order by laying down once and for all a fixed set of axioms and rules of 
inference?” (ibid. 104) We have been investigating this connection through the insights of 
Douglas Hofstadter, by way of citations taken from his iconic work entitled *Gödel, Escher, 
Bach: An Eternal Golden Braid*. In this study, Hofstadter attempts to define the shared universal 
ideas that science, art and music struggle to express. By focusing on the “art” category, we may 
find a connecting thread to Calvino and Borges in the following position: “There is a conflict 
between the finite and the infinite, and hence a strong sense of paradox. Intuition senses that 
there is something mathematical involved here.” (ibid. 15) Gödel’s “Incompleteness Theorem,”
embodied in this vague notion but also defined by its inability to be fully expressed, is once again reflected in Calvino’s Palomar, who cannot ever completely isolate his subject of study; in several Borgesian narrators who grapple with Alephs, Zahirs, and infinite books; and even in Calvino’s nonexistent knight, Agilulf, himself a representation of spiraling infinity. These characters fail to gain the wholeness or insight that they seek against the unstoppable current of infinite time and infinite space, and necessarily so; “Gödel says that no sufficiently powerful formal system can be perfect, in the sense of reproducing every single true statement as a theorem… The fact that truth transcends theoremhood, in any given formal system, is called the ‘incompleteness of that theorem.” (ibid. 86) The incompleteness of understanding that plagues the narratives of Calvino and Borges is assuredly an extension of this same idea:

I think it can have suggestive value to translate Gödel’s Theorem into other domains, provided one specifies in advance that the translations are metaphorical and are not intended to be taken literally… The other metaphorical analogue to Gödel’s Theorem which I find provocative suggests that ultimately, we cannot understand our own minds/brains… All the limitative Theorems of metamathematics and the theory of computation suggest that once the ability to represent your own structure has reached a certain critical point, that is the kiss of death. It guarantees that you can never represent yourself totally. (ibid. 696-7)

Palomar, in a section entitled “Model of Models,” reaches this “kiss of death.” He is unable to create a system that mimics the gargantuan scope and endless fluidity of reality.

In Mr. Palomar’s life there was a period when his rule was this: first, to construct in his mind a model, the most perfect, logical, geometrical model possible; second, to see if the model was suited to the practical situations observed in experience; third, to make the corrections necessary for model and reality to coincide… Mr. Palomar’s rule had gradually been changing: now he needed a great variety of models, whose elements would be combined in order to arrive at that one would best fit reality, a reality that, for its own part, was always made up of many different realities, in time and space. (Calvino 108-110)

One can practically trace the entire human exercise of scientific inquiry in this short passage – from early attempts to create a static cosmological model all the way to the vertiginous
implications of special relativity and quantum physics. Like Cantor, Palomar is maddened by reality’s resistance to his imposition of structure; like Heisenberg, he is befuddled when, in grasping one variable, another slips through his fingers; and like current scientists such as Brian Greene, Michio Kaku and Stephen Hawking, Palomar finally resigns himself to the idea that “the model of models… must serve to achieve transparent models, diaphanous, fine as cobwebs, or perhaps even to dissolve models, or indeed to dissolve itself.” (ibid. 111)

**Black Holes**

So far in this section we have dwelt largely on mathematical singularities; now, we will move into a discussion of the physical singularities known as “black holes.” The concept should not be new to anyone, as black holes have held a terrifying and titillating place in Western popular culture for quite some time.\(^\text{23}\) At its most basic level, a black hole is a region of space whose density is so immense – usually the result of the implosion of a huge, dying star – as to approach infinity. This extreme compression causes spacetime to warp into a cone-shaped structure that peaks, at its center, in a pin-point of infinite density: a singularity. The singularity’s characteristics are still mostly unknown; other than its density, not much can be audited about its more intimate properties since light particles, which communicate information to us, cannot escape its inexorable pull. Studies on black hole radiation and X-rays have yielded novel details about the physical qualities of black holes, but there appears to be a cosmic curtain that remains closed on their deepest structures. Nonetheless, the implications are unsettling – Brian Greene, in *The Hidden Dimension*, tells us that:

\(^{23}\text{We might cite any number of films, television shows, video games and books, ranging from *The Black Hole* (1979), *Event Horizon* (1997) and the *Battlestar Galactica* television series, to the ongoing Mass Effect series of role-playing video games, to bestselling works of fiction by Arthur C. Clarke and Larry Niven – just to name a few. - MR}
A singularity is any physical setting, real or hypothetical, that is so extreme (huge mass, small size, enormous spacetime curvature, punctures or rips in spacetime fabric) that quantum mechanics and general relativity go haywire, generating results akin to the error message displayed on a calculator when you divide any number by zero. (Greene 111)

Even earlier, in his 2000 bestseller The Elegant Universe, Greene presented what is perhaps the strangest aspect of a black hole singularity:

A straightforward application of general relativity, going all the way back to [Karl] Schwarzschild in 1916, shows that the enormous mass and energy crushed together at the black hole’s center causes the fabric of spacetime to suffer a devastating rift, to be radically warped into a state of infinite curvature – to be punctured by a spacetime singularity… Time itself comes to an end at the heart of a black hole. (Greene Elegant 343-4)

It is not difficult, then, to intuit why the concept of the black hole/singularity has captivated the imaginations of authors, directors and the general public – its mere existence seems to violate the rules of everyday existence, allowing the impossible to somehow become possible. In recent years, theoretical discussions have migrated to the possibility of mankind eventually creating artificial black holes, which would allow us to not only observe more closely the properties of singularities but also to potentially affect time and space in new and useful (or destructive) ways. Whether or not this will ultimately become possible is very much up for debate, although small successes have been seen recently at the Large Hadron Collider operated by CERN in Switzerland. Brian Greene defines the parameters of this possibility in The Fabric of the Cosmos:

Although we normally think of black holes as gargantuan structures out in deep space, it’s been known since the early days of general relativity that if you crammed enough matter together in the palm of your hand, you’d create a tiny black hole. This doesn’t happen because no one’s grip – and no mechanical device – is even remotely strong enough to exert a sufficient compression force. Instead, the only accepted mechanism for black hole production involves the gravitational pull of an enormously massive star’s overcoming the outward pressure normally exerted by the star’s nuclear fusion processes, causing the star to collapse in on itself. But if gravity’s intrinsic strength on small scales is far
greater than previously thought, tiny black holes could be produced with significantly less compression force than previously believed. (Fabric 403)

To the literary mind, these wondrous possibilities need not be mired in the argument of hypothesis versus reality – as with all other ideas, fiction finds itself to be uniquely unfettered and, perhaps, most capable of all disciplines to take up the business of contemplating black holes with the aim of advancing knowledge. Greene states this very same idea:

Extraordinary emblems of math’s ability to illuminate the dark corners of the cosmos, black holes have become the cynosures of modern physics. Besides serving as a boon for observational astronomy, black holes have also been a fertile source of inspiration for theoretical research by providing a mathematical playground in which physicists can push ideas to their limits, conducting pen-and-paper explorations of one of nature’s most extreme environments. (Hidden 276)

These “pen-and-paper explorations,” we might posit, are in no way distinct from the activities of other creative thinkers of the ilk of Calvino and Borges; “The Aleph” and Cosmicomics, in particular, are indeed “playgrounds” for the physical and philosophical consequences of singularities of various forms. Greene is not the only physicist with such a broad understanding of the interdisciplinary epistemology involved in the contemplation of black holes; Matthieu Ricard, a former scientist who left his profession to become a Buddhist monk, states in a dialogue with the physicist Trinh Xuan Thuan that

In the vicinity of a “black hole,” one second can stretch to eternity. As in Buddhism, relativity teaches us that the idea of a past already gone and a future still to come is mere illusion, given that my future can be someone else’s past and a third person’s present – it all depends on our relative motions. Time does not pass, it is simply there. (Ricard 277)

Deriving his stance from a more Eastern perspective than that of Greene, Ricard bridges the perceived gap between science and philosophy by offering a meditation on the concept of the singularity that succeeds in tying together not only all people, but all times and places.
What is most crucial to our study is confirmation that both Calvino and Borges had an awareness of black holes and the phenomenon of singularities. Domenico Scarpa, a Calvino scholar, provides some admittedly anecdotal evidence of the former:

Calvino e [Primo] Levi erano entrambi lettori della rivista di alta divulgazione più diffusa a livello mondiale, <<Scientific American>>, e della sua edizione italiana <<Le Scienze>>. In quest’ultima apparvero tra il 1972 e il 1974 due importanti articoli, firmati rispettivamente da Roger Penrose e da Kip S. Thorne, i quali riferivano a loro volta sugli esperimenti e le riflessioni dello scienziato che in questo settore [i.e. black holes] si sarebbe conquistato fama mondiale negli anni successivi: Stephen Hawking. (Scarpa 297)

While highly probable, this citation does not prove conclusively that Calvino had an understanding or awareness of black holes. Fortunately, more primary evidence can be found in several of Calvino’s articles published in the Corriere della sera, and in particular one installment of “Mr. Palomar’s Observatory” from 1975 (cited by Mario Porro in “Images and Scientific Knowledge in Calvino”).

In one of the pieces of the column entitled ‘Mr. Palomar’s Observatory’, in the Corriere della sera, Calvino admits that he is a collector of cosmological models: they fulfill his sensitivity ‘alle suggestioni delle immagini plastiche’, a sensitivity that is generally more powerful than philosophical implications. In September 1975, Mr. Palomar had tried to provide an explanation of how he understands black holes, those ‘innimaginabili oggetti celesti’. In response, he received a series of polite critical observations from the astronomer Margherita Hack, to whom he responded in the same column in October… On this occasion Calvino clarifies his position saying that figurative thought functions according to an elementary or primitive logic, based on the mechanism of analogy, which can be broken down into very simple oppositions: inside and outside, full and empty, light and dark, high and low, and so on. ‘E puó accadere alle volte che queste strade incrocino quelle della scienza di oggi, o le accompagnino per un tratto’. (Porro 62)

In addition to explicitly confirming Calvino’s interest in and knowledge of black holes, this quote also provides an additional excursus on what he saw to be the primacy of analogy in the generative processes of both science and literature. By linking both disciplines at their common root, Calvino makes a clear statement about the shared mental and philosophical processes of
fiction and physics. In both cases, abstract logic can assist in conceptualizing ideas that seem “unimaginable,” and one might therefore justly seek to employ such creative thought patterns in forming an understanding of physical phenomena.

Borges, in turn, indirectly demonstrated an awareness of the phenomenon of black holes through several of his book reviews and stories – by analyzing works like “The Book of Sand,” “The Aleph” and “The Library of Babel,” we can be certain of his fluency in the defining characteristics of singularities. In Borges, though, singularities can pop up in the most unlikely of places. Aside from the examples of Cantorian infinity that we have already identified in Borges, a different example comes in the form of a small, intensely heavy metal cone, a tiny totem of an almighty being that exists only within the made-up universe of a provocative story entitled “Tlön, Uqbar, Orbis Tertius.” Borges relates its attributes:

In his delirium, several coins had slipped from his wide gaucho belt, as had a gleaming metal cone a die’s width in diameter. A little boy tried to pick the cone-shaped object up, but in vain; a full-grown man could hardly do it. I held it for a few minutes in the palm of my hand; I recall that its weight was unbearable, and that even after someone took it from me, the sensation of terrible heaviness endured. I also recall the neat circle it engraved in my flesh. That evidence of a very small yet extremely heavy object left an unpleasant aftertaste of fear and revulsion… Those small, incredibly heavy cones (made of a metal not of this world) are an image of the deity in certain Tlönian religions. (CF 80)

“Tlön, Uqbar, Orbis Tertius” is, first of all, the tale of a tale. It explores the power of fiction and the potential for the “false” to come to replace the “true” – or, better still, it explores an occasion upon which true and false reach an existential parity. In this story, the reader comes to know that a shadowy group of intellectuals has invented a world known as “Tlön” by way of a series of obscure encyclopedia entries. Borges’ narrator, in attempting to verify the reality of such a place, is drawn into an ever-developing description of the elements of this other universe. Strangely enough, the fictitious Tlönians (as they are called) deny the reality of their own world, which not
only complicates Borges’ research but also challenges the reader to align themselves with either Borges’ relative “reality” or Tlön’s fiction. The uncharacteristically lengthy story ends with the statement that, as Tlön receives increasing attention from researchers, it may come to replace our own world. The aforementioned metal disk – which is never given a name – represents, then, not only an otherworldly substance of extreme weight and density, but also a manifestation of the terror and confusion that an infinite plurality of realities can produce in whoever regards it. Its placement as a quasi-religious artifact within a story that is intended to complicate the very nature of reality is not accidental – Borges seems to urge the reader, through this image, to envision something that tends toward a black hole: heavy enough to warp time and space, dense enough to serve as a gateway to another universe, and so difficult to conceive of as to generate nothing short of abject fear and hopelessness in humanity, as the Earth itself is pulled into its annihilating spiral.

“Tlön, Uqbar, Orbis Tertius” does not represent the only appearance of black-hole imagery in Borges’ cycle, however. In “The Disk,” a Norse woodcutter encounters a man who possesses a coin – the “disk of Odin” – that has only one side. Its allure compels the woodcutter to murder the coin’s owner, causing the coin to hurtle and land with its visible side facing down, never to be found again. While extremely short, this particular story generates a high density of implications relating to infinitude and singularity. Floyd Merrell has commented on this tale, stating that “this coin is a metaphor for infinity, and as such the coin can have no reverse side, for since infinity according to one particular view is incompletable, the reverse side must therefore be invisible.” (Merrell 7) Less compelling, but ultimately valid, is Guillermo Boido’s estimation that “Borges arranca el círculo euclideano del plano, lo lanza a un espacio tridimensional, lo materializa y lo convierte en el disco de Odin, que tiene un solo lado.” (Boido
52) Between these two critiques of Borges’ single-sided disk we can locate a hybridized view that classifies a disk that exists in three-dimensional space while simultaneously violating the rules of Euclidean geometry as a physical singularity. If it exists in three-dimensional space, it must have more than one side – it cannot have fewer than two sides or fewer than three dimensions. Yet it does; and its impossible existence so inflames the passions of the woodcutter that he murders a stranger in order to possess it. This moment of contact with the perplexing, maddening nature of infinity echoes the images we have already seen, as well as those to come.

There exists a physical limit, however, to the aspects of a black hole that can actually be seen or measured – since light is trapped by its pull, the same light cannot reach us to convey information about what lies beyond the event horizon. Indirect methods can be used to triangulate certain properties of black holes, but the singularity at the center of the black hole cannot typically be witnessed. There is only one possible version of a singularity that would potentially allow the observer to peer into its abyss, and we will be utilizing this theoretical possibility in order to advance our discussion on the usage of such images in the fictions of Borges and Calvino. This phenomenon is called a “naked singularity,” and Floyd Merrell has handily linked this concept to what is witnessed by the narrator of Borges’ infamous story “The Aleph”:

The Aleph, I believe… enjoys a contemporary counterpart in the concept of a space-time singularity, especially the so-called “naked” singularity… Ordinary singularities are the product of “black holes,” whose gravitational force is of such magnitude that light is trapped within them. There are also special types of singularities, “naked” singularities, which are theoretically formed in the absence of black holes… In general, the difference between a black hole and a naked singularity – “unclothed” with a black hole – is that light can escape one but not the other… In the collapse of a star to a naked singularity, light rays are convoluted around the singularity, which is a charged, rotating hole unlike the nonrotating black hole, and after spiraling around it for a period of time, the rays can finally escape to the outer region, and hence theoretically they now become observable. (Merrell 145-147)
The possibility of witnessing a naked singularity is infinitesimal, of course, even by astronomical standards. John D. Barrow, author of *The Infinite Book*, a popular primer on infinity, reinforces this caveat:

Are naked singularities real? Roger Penrose proposed that there “exists a principle of ‘cosmic censorship’ in Nature, so that all singularities, or physical infinities, where the laws of Nature break down, are hidden from the outside by horizon surfaces. Their consequences are trammeled up by the extreme curvature to space and time that accompany the formation of very high density regions. They are quarantined by the horizon. There have been many attempts to prove that this hypothesis of cosmic censorship is always true: that naked singularities never occur in Nature, they are all hidden by horizons. So far, it has not been possible to prove that it is universally true, but all the plausible situations that appear to threaten it have turned out to fail. It continues to be suspected that it will turn out to be true, but with certain caveats. (Barrow 107-8)

Stephen Hawking, too, has commented on the likelihood of naked singularities, stating that they “would offer great possibilities for travel in space and time, but unfortunately it seems that these solutions may all be highly unstable.” (Hawking 91)

But, once again, fiction allows us the opportunity to grasp, rotate and inspect such images despite the current technological and scientific limitations of humanity. Being able to observe a singularity involves seeing not only the singularity itself, but a full manifestation of infinity – Merrell explains that such an experience could “afford [the observer] an extraordinarily dramatic moment, for the singularity is exposed to and exposes the entire universe.” (ibid. 147) Other clues link “The Aleph” with a naked singularity as well; Merrell notes quite perspicaciously that “in an instant an infinite quantity of light arrives [from a naked singularity]. Significantly, Borges tells us that ‘all stars, all lamps, all sources of light’ were in the Aleph, and that the light emanating from it was of ‘unbearable brilliance’ when he saw it in that single ‘gigantic instant.’ (ibid. 148) The epigraph from Hamlet with which Borges begins “The Aleph” is also a sign of his complicity in the metaphor of a singularity: “O God, I could be bounded in a nutshell and
count myself King of infinite space.” (CF 274) It should also be noted that Merrell is far from being the only scholar who has pegged “The Aleph” as a representation of a singularity – Héctor Vecetich, for one, states in “Espacio y tiempo en Borges” that “En ‘El Aleph’… Borges sugiere una posible visión de una singularidad.” (Vucetich 64)

There are numerous examples of singularities in Calvino’s fictions, as well. In fact, an echo of an Aleph can even be found in the description of a city called “Zoe” in Invisible Cities: “In every point of this city you can, in turn, sleep, make tools, cook, accumulate gold, disrobe, reign, sell, question oracles… if existence in all its moments is all of itself, Zoe is the place of indivisible existence.” (Calvino 34) The city of Zoe can therefore be regarded as an experiential singularity in the same way that the Aleph seems to represent all points of the universe in full simultaneity (as Borges himself clarifies in “The Aleph”) and not in succession. (CF 283)

Another work by Calvino entitled Se una notte d’inverno un viaggiatore..., with its dialogic multiplicity and schizophrenic approach to narrative, has also drawn comparisons to a singularity, with Mario Porro stating in “Networks and Knots: The Discrete and the Continuous in Literature – Italo Calvino and Carlo Emilio Gadda” that “space itself in Se una notte is ‘sovraccarico, denso,’ so that ‘le linee tendono a contorcersi, a diventare sinuose come il fumo del bracierre.’” (Porro 264)

We can advance our discussion of the appearances of possible singularities in Calvino’s works with an abstract sighting taken from The Castle of Crossed Destinies; specifically, within a story that is based on a section of Ludovico Ariosto’s Orlando Furioso. “The Tale of Astolpho on the Moon” – named analogously to its precursor – is a re-telling of this infamous chapter of the Furioso, but with the added frame of having been spontaneously generated from random selections of tarot cards (as is every other tale in this particular book). The narrative recounts
Astolpho’s task of retrieving the impassioned crusader Orlando’s sense from the surface of the moon, from a storeroom of vials that contain all untold stories and unlived histories.

‘You must ascend to heaven, Astolpho’ (the angelic Arcanum of The Last Judgement indicated a superhuman ascension) ‘up to the pale fields of the Moon, where an endless storeroom preserves in phials placed in rows’ (as in the Cups card) ‘the stories that men do not live, the thoughts that knock once at the threshold of awareness and vanish forever, the particles of the possible discarded in the game of combinations, the solutions that could be reached but are never reached…’ (Calvino 37)

The more immediate similarities to Borges’ “Library of Babel” and “Garden of Forking Paths” are, of course, obvious; a storeroom, plane or dimension containing all possible historical outcomes is in line with what will be discussed in the next chapter of this study in a relation of the consequences of quantum physics. However, it is the last paragraph of Calvino’s tale that will demonstrate why this particular image suggests the existence of a black hole.

On the white fields of the Moon, Astolpho encounters the poet, intent on interpolating into his warp the rhymes of the octaves, the threads of his plots, his reasons and his unreasons. If he inhabits the very center of the Moon – or is inhabited by it, as by his deepest nucleus – he will tell us whether it is true that the Moon contains the universal rhyme-list of words and things, if it is the world full of sense, the opposite of the senseless Earth. ‘No, the Moon is a desert.’ This was the poet’s reply, to judge by the last card put down on the table: the bald circumference of the Ace of Coins. ‘From this arid sphere every discourse and every poem sets forth; and every journey through forests, battles, treasures, banquets, bedchambers, brings us back here, to the center of an empty horizon.’ (ibid. 38-9)

The poet, existing in the center of a dense sphere much like the singularity of a black hole, attempts to “warp” all things into his area; we should recall at this point that the physical function of a space-time-warping black hole is the exactly the same. In fact, the density of the center of this sphere is so great that the poet and the moon have seemingly fused into a single entity, along with all other “discourses” and “poems,” e.g. all possible narratives and objects. The infinitely dense singularity within a black hole – as well as Borges’ Aleph – flattens time
and space and allows all things to occupy the same point in space. How fitting, as well, that Calvino chose to seal this paragraph with the word “horizon” (orizzonte in the Italian version), since it explicitly defines the event horizon, i.e. the area of a black hole that begins to tend toward emptiness and past which no light can escape. The evocation of the “bald circumference of the Ace of Coins” might also cause us to recall Borges’ own disk of Odin, which represents infinity in a rather similar monetary image. Nevertheless, whether he intended to or not, Calvino seems to have set a singularity at the center of this story, which is itself framed within an increasingly elaborate game of entropic combination.

Calvino’s Cosmicomics, on the other hand, contains a more explicit depiction of a singularity; “All at One Point” lightheartedly analyzes the experience of existence prior to the Big Bang, when all things (and, indeed, all space) occupied a single, infinitesimally tiny point. Domenico Scarpa, in “Calvino, Levi e la scoperta dei buchi neri,” states that “Calvino prova a immaginare l’universo un attimo prima del Big Bang, quando tutta la materia è concentrata in un luogo privo di dimensioni e di tempo.” (Scarpa 302) Alan Lightman, a physicist writing in the scientific journal Nature, agrees that “it seems that Calvino is attempting to fathom how much of a reality can be created without familiar geography of time and space. He plays with science the way a found-object artist throws together bolts of silvered glass, odd metal brackets, bits of coloured paper.” (Lightman 329) “All at One Point” begins with a recapitulation of Edwin Hubble’s discovery of the continual expansion of the universe and the consequent understanding that all matter must necessarily have converged at one point prior to the beginning of such an expansion. What follows this historical citation is unexpectedly lighthearted: a community of beings, all with curiously Italian temperaments and speech patterns, cramped and living together in the center-point of a singularity that is described in much the same way as one would describe
a tenement building. These beings engage in petty squabbles, struggle and cope with the immense lack of space and diversity of disparate opinions, and lament that there is not enough room for the matronly Mrs. Ph(i)Nk$_{\theta}$ – the common object of their boyhood lust – to make all of them a batch of homemade pasta. Narrative aside, however, this story makes clear the fact that Calvino had a strong facility with the physical characteristics of singularities, which was assuredly nurtured by his extensive readings in science and his natural academic curiosity.

*T zero*, which Calvino published soon after *Cosmicomics*, provides an extremely succinct image of a black hole, and perhaps one that is more accurate than others in its relative brevity.

“The Origin of the Birds” narrates Qfwfq’s struggle to accept the reality of the spontaneous evolution of birds from reptiles, as well as the collision of the Earth with another land mass – a cataclysm that yields, for a moment, what Kerstin PIlz calls “a glimpse of the desired holistic universe. It is a cosmic vision that can only last a split second.” ([Mapping Complexity](#) 48)

Calvino’s narration reads:

The two worlds, having touched, bounced apart again, then were rejoined, then separated once more. In one of these clashes I found myself flung to the other side, while the empty abyss yawned again and separated from my world. I looked around: I didn’t recognize anything. Trees, crystals, animals, grasses – everything was different. Not only did birds inhabit the branches, but so did fish (after a manner of speaking) with spiders’ legs or (you might say) worms with feathers. Now it’s not that I want to describe to you the forms of life over there; imagine them any way you can, more or less strange, it doesn’t matter. What matters is that around me there were displayed all the forms the world could have taken in its transformations but instead hadn’t taken, for some casual reason or for some basic incompatibility: the rejected forms, unusable, lost. (Calvino 19)

After a lengthy examination of this new, foreign world, Calvino’s narrator, finding himself engaged in a moment of amorous ecstasy with the Queen of the Birds, reaches the aforementioned “holistic,” cosmic vision;

For a fraction of a second between the loss of everything I knew before and the gain of everything I would know afterward, I managed to embrace in a single
thought the world of things as they were and of things as they could have been, and I realized that a single system included all. (ibid. 26)

Putting the sexual imagery aside for the moment, we might also regard this description of a fleeting communion with the infinite as analogous to what has very recently been observed in the Large Hadron Collider at CERN; if black holes or singularities represent points of infinite density in the universe, and if these infinitely dense points hold the potential to contain within them (according to our understanding of infinity) the totality of all space and perspectives, then what Qfwfq experiences following the collision of objects in “The Origin of the Birds” can be easily compared to the microscopic, infinitesimally short-lived black holes created through the forced collision of subatomic particles at CERN. Though they only exist for a fraction of a nanosecond, these singularity events hold the capacity, perhaps, to lay bare the underlying, infinite structure of the universe. That Calvino’s playful fiction even approaches comparison to such an advanced scientific concept – and then, more than 50 years ago – is nothing short of extraordinary.

A final thought on Calvino’s treatment of black holes comes once again from Domenico Scarpa, who comments on Calvino’s demonstrated awareness of supernovae and the surprisingly positive symbolism that he attributes to the consequences of their violent deaths: “Ecco che, dice Calvino, le stelle di neutroni con la loro implosione vengono a offrirci una nuova figura positiva, un emblema di ‘concentrazione massima delle proprie facoltà, contrazione come assorbimento di forza, focalizzazione e immedesimazione e compattezza interiore.’” (Scarpa 304) These qualities are all compatible with the literary concepts that Calvino would come to define as ideals in Six Memos for the Next Millennium – lightness, quickness and exactitude, specifically. There is an acuity to the singularity – a compact, precise efficiency of representation that can serve, in Calvino’s estimation, as an ideal model for the transmission of information.
A final image to be discussed in this chapter is that of the *wormhole*, which is a radical warping of space-time made hypothetically possible through the existence of black holes. Brian Greene offers a detailed description of this phenomenon:

A *wormhole* is a hypothetical tunnel through space. A more familiar kind of tunnel, such as one that’s been bored through the side of a mountain, provides a shortcut from one location to another. Wormholes serve a similar function, but they differ from conventional tunnels in one important respect. Whereas conventional tunnels provide a new route through existing space – the mountain and the space it occupies exist before a tunnel is constructed – a wormhole provides a tunnel from one point in space to another along a new, previously nonexistent tube of space. Were you to remove the tunnel through the mountain, the space it occupies would still exist. Were you to remove a wormhole, the space it occupied would vanish. (Fabric 461)

Rather than acting as a conventional tunnel to allow the shortest distance between two points to be traversed, a wormhole instead pinches two points in space together, *eliminating* the space that divides them.24 This distinction is crucial to our visualization of wormholes, since it separates the concept of a universe of discrete points from that of a continuous universe that is both flexible and prone to warping. The scholar Mario Porro points out this distinction when discussing Marco Polo’s voyage in Calvino’s *Invisible Cities* in his article “Networks and Knots: The Discrete and the Continuous in Literature,” stating that “of Marco Polo’s itinerary [in *Invisible Cities*], punctuated by rest stops, we know only these breaks and not the path that leads from one place to another.” (Porro 258) Indeed, we readers are never shown the route of Polo’s traversals between the cities of the Khan’s dominion; each city represents a discrete point, and the continuum that surrounds them is never addressed. Could it be, then, that there simply is no space at all between them? Or, potentially, that the space between them is warped and pinched through some wormhole effect, eliminating the need to cross space in order to move from one to the next?

24Stephen Hawking also touches on a similar description in *A Brief History of Time*: “It might be that one could warp space-time so that there was a shortcut between A and B. One way of doing this would be to create a wormhole between A and B. As its name suggests, a wormhole is a thin tube of space-time which can connect two nearly flat regions far apart.” (Hawking 163)
There is, unfortunately, a lack of evidence in the text that Calvino deliberately intended to employ this particular technique in *Invisible Cities*. However, he provides a much more concrete example of a wormhole in “The Count of Monte Cristo,” which appears in *T zero*.

Itself a re-telling of the middle portion of Alexandre Dumas’ eponymous novel, Calvino’s “Count of Monte Cristo” has Edmond Dantés as its narrator, who details the frantic efforts of the Abbé Faria to tunnel his way out of their shared prison, the impenetrable Chateau d’If. Faria has been wholly unsuccessful in his attempts to escape, but he continues nonetheless, and the scrape of his digging tools against the castle’s stones is unrelenting. Strangely enough, Faria’s own experience of moving through his pointless tunnels seems to exactly mimic the expected effects of moving through a wormhole in space. Edmond describes it in this way:

> At times I hear scratching at the ceiling; a rain of plaster falls on me; a breach opens; Faria’s head appears, upside-down. Upside-down for me, not for him; he crawls out of his tunnel, he walks head down, while nothing about his person is ruffled, not his white hair, nor his beard green with mold, nor the tatters of sackcloth that cover his emaciated loins. He walks across the ceiling and the walls like a fly, he sinks his pick into a certain spot, a hole opens; he disappears. Sometimes he has hardly disappeared through one wall when he pops out again from the wall opposite: he hasn’t yet drawn his heel through the hole here when his beard is already appearing over there. He emerges again, more weary, skeletal, aged, as if years had passed since the last time I saw him. (Calvino 142)

What is first noticed about this description is the relativistic approach to space and gravity – like the perspectives in an M.C. Escher drawing, Edmond and the Abbé seem to each exist concurrently in separate space-time paradigms; what is “up” for one is “down” for the other. Time seems to also pass at different rates, with Faria aging more rapidly (perhaps due to the effects of general relativity related to black-hole density). The more interesting detail in this citation, however, relates directly to the wormholes we have already discussed. Calvino’s narrator tells us that no space seems to separate the entrances and exits of the tunnels through which Faria travels – as soon as his head enters one hole, it exits the corresponding hole.
simultaneously. This, of course, suggests that there is no space between the entrance and exit – if there were, there would be a lapse between when his head entered one end and exited the other. This means that the currently-accepted rules of theoretical physics are applicable here, and that the space that would normally need to be traversed is instead being bridged or “pinched” by way a warping of space-time. Of course, while technically acting as shortcuts, these wormholes never seem to yield an exit from imprisonment for the narrator or his companion.

We have shown that the concept of the wormhole exists within both theoretical physics and certain works of creative fiction; as a conclusion to this chapter, we will briefly reflect on the potential for their existence in physical reality. Stephen Hawking, perhaps the one human being best versed in such details, provides an analysis of this possibility in relation to time travel in A Brief History of Time:

To do this, or to warp space-time in any other way so as to permit time travel, one can show that one needs a region of space-time with a negative curvature, like the surface of a saddle. Ordinary matter, which has a positive energy density, gives space-time a positive curvature, like the surface of a sphere. So what one needs, in order to warp space-time in a way that will allow travel into the past, is matter with negative energy density… We thus have experimental evidence both that space-time can be warped (from the bending of light during eclipses) and that it can be curved in the way necessary to allow time travel (from the Casimir effect).

(Hawking 164-5)

While this analysis relates specifically to wormholes in the function of time travel, the physics are the same – space-time can theoretically be bridged across areas of negative curvature, thereby allowing particles, information, and light (and eventually humans?) to move from one discrete point in space or time to another without having to cross any physical space at all.

All of the disparate examples that have been provided in this chapter serve as signs that Borges and Calvino – both scientifically-minded, well-read writers of fiction and non-fiction alike – engaged in literary explorations of the infinite by using imagery and themes that have
strong analogues in the mathematics and astrophysics of their time. Among these, black holes, singularities, and infinite value sets are the foremost. In the coming chapter, we will move our discussion into increasingly stranger and more fecund imagery by focusing on the elements of quantum physics – from Erwin Schrödinger’s superposed states, to quantum entanglement, multiverses and time travel – that have found their way into the fictions of Italo Calvino and Jorge Luis Borges.
As we move deeper into our analysis of the scientific themes and imagery found in the fictions of Jorge Luis Borges and Italo Calvino, we must now confront what is arguably the most challenging theoretical material currently known to human science – quantum physics. By confronting several different theories and structures and drawing comparisons with specific works of fiction by Borges and Calvino, we will continue to trace a defined route through the interdisciplinary fictional exercises of these two authors while simultaneously demonstrating the creative roots of numerous scientific breakthroughs. By utilizing concepts such as superposition, quantum entanglement and multiverse theory in our close readings of fictional texts, we will find a number of compelling ways to relate Borges and Calvino’s creative output to the science of their epoch and ours.

Just as literature has been perennially driven by aesthetic considerations, so, too, has science. As Roger Newton relates,

Many scientists, Schrödinger and Einstein among them, were guided in their search for new insights by aesthetic considerations; beauty was an important criterion for them. This does not mean that they ignored experimental facts, but they were able to generate abstract mathematical ideas relying on their personal sense of beauty and to retain their faith in being right even when, among the always-present welter of initially confusing and unsorted experimental observations, some appeared to prove them wrong. (Newton 237)

As was shown in our earlier discussion of the methodology-breaking tendencies of Paul Feyerabend, good science can be driven at each turn by both rigor and wild abandon – theorization is itself a fictive act, regardless of how its resultant conjectures come to be proven (according to a system of logic that, as we have seen, is also devoid of any “absolute” claim to verifiability). As we begin this chapter with Erwin Schrödinger’s concept of superposition, it is
crucial that we not lose sight of this unifying detail, which demonstrates the common root of
science and literature.

As an introduction to quantum wave function – which will then lead us to an
understanding of superposition – Roger Newton’s description will do:

The state of a physical system, such as a collection of particles, determined in
classical Newtonian mechanics by specifying all their positions and momenta, is
determined in quantum mechanics by specifying its wave function. While the
behavior of this wave function follows the Schrödinger equation in a deterministic
manner – a given state now determines the state at a later time – knowing the
wave function does not imply knowing all the physical attributes of a system
precisely; for some of them the wave function implies only probabilities. The
concept of causality is lost: we cannot trace every event back to an earlier event,
or set of events, causing it… The Schrödinger equation has the property –
technically speaking, it is linear and homogenous – that if \( f \) and \( g \) are two
solutions of it, then so is \( f + g \): this is called the superposition principle. (Newton
242-43)

To condense this admittedly heady discourse, we might simply rephrase thusly: quantum physics
is based not on pure causality, but on waves of probability. Simply put, Schrödinger’s wave
function defines the probability of a particular event occurring, but it is not until the wave
“collapses” (e.g. the event occurs) that one can actually, precisely know whether it will. If \( f \) can
occur or \( g \) can occur, quantum physics also allows that both \( f \) and \( g \) could occur, even if they are
mutually exclusive. This paradox, strange as it seems, is one of the foundational concepts of
modern theoretical physics.

Physicist Brian Greene, to whom we have turned at several points in our study, offers a
measure of sympathy in *The Hidden Reality*:

I understand full well if this explanation leaves you shaking your head. There’s no
denying that quantum dogma sounds a lot like snake oil. I mean, along comes a
theory that proposes a startling new picture of reality founded on waves of
probability and then, in the very next breath, announces that the waves can’t be
seen. (Greene 230-1)
Likewise, Michio Kaku comments on the logical conditions that create superposition, which is essentially a theoretical image of reality composed of two superimposed or overlaid states, each of which carries a defined probability of occurring.

Quantum theory also states that you never really know the state of the particle until you have made an observation. Before a measurement is made, the particle can be in one of a variety of states described by the Schrödinger wave function. Thus before an observation or measurement can be made, you can’t really know the state of the particle. In fact, the particle exists in a nether state, a sum of all possible states, until a measurement is made. (Hyperspace 260)

The most common thought experiment associated with superposition (and with Schrödinger) is what has come to be known as “Schrödinger’s Cat” – Floyd Merrell (along with David Lindley25 and Michio Kaku,26 in varying degrees of potency) has provided an excellent summation of this notoriously difficult conceptual exercise.

Suppose we put a cat in an enclosed box containing a mechanism triggered by the possible radioactive decay of a nucleus that is capable of breaking a flask of cyanide gas. If the nucleus decays, the cat dies; if not, it remains alive. There is at the outset, in a rather metaphorical way of speaking, an overlapping “superposition” of two possible worlds: decayed nucleus and dead cat or intact nucleus and live cat. The question is, before we open the box at the designated time, is there a potential state, two “superposed” waves, entailing two nonactualized cats: live-dead? If so, then neither is “real” until we lift the lid of the box and take a peek (interact with) its “contents.” In such a case, and contrary to our better judgment, we are forced to conclude that we the spectators bring one of the two worlds into existence. (Merrell 157)

25.“This poor creature sat helplessly in an enclosed box, accompanied by a small radioactive sample and a Geiger counter hooked up to a hammer that will smash open a vial of poison. In the course of an hour, Schrödinger stipulated, there’s a 50 percent chance that the radioactive sample will trigger the Geiger counter and thereby kill the cat. The radioactive atoms themselves, at that moment, must be described quantum mechanically as being equal parts intact and decayed, since they combine both possibilities. But then, Schrödinger insisted, the cat that’s linked to the atom must be likewise described, in quantum language, as equal parts dead cat and live cat.” (Lindley 194-5)

26.“According to quantum mechanics, we cannot predict with certainty when a single uranium nucleus will disintegrate. We only can calculate the probability of billions upon billions of nuclei disintegrating. Therefore, to describe a single uranium nucleus, quantum mechanics assumes that it is a mixture of two states – one where the uranium nucleus is inert, the other where it has decayed. The cat is described by a wave function that contains the possibilities that it is both dead and alive. In other words, we must assume statistically that the cat is a mixture of two states.” (Kaku Beyond Einstein 45)
Schrödinger’s much put-upon cat, then, has the remarkable quality of remaining, prior to verification, theoretically both alive and dead, simultaneously.

While the creative implications of such a remarkable state are rather obvious, more can be said about what this means in terms of fiction and imagination. Schrödinger himself commented on the unreal quality of the image presented by superposition, just as Matthieu Ricard reminds us by stating that “it is better not to view a particle as a permanent entity, but rather as an instantaneous event. Sometimes these events link together to create the illusion of permanent entities.” (Ricard 85) An “illusion,” then, is the defining nature of the objects and occurrences that surround and envelop us in reality, according to Schrödinger – we, too, are part of this illusion.

The bridge between our discussion and the realm of creative fiction can be established through Guillermo Boido:

Podríamos pensar que al cabo del lapso de un segundo se han generado dos historias posibles: en una de ellas, el gato muere; en la otra, sobrevive. Con una argumentación similar, al cabo de dos segundos se habrán generado tres historias posibles: la del gato que ha muerto al cabo de un segundo, la del gato que ha muerto al cabo de dos segundos y la del gato que sobrevive al cabo de dos segundos. Esta secuencia temporal, arborescente, de tiempos e historias paralelas, podría ser extendida indefinidamente. (Boido 51)

We will eventually come to connect this type of idea with the images presented in Borges’ “The Garden of Forking Paths,” but first we will briefly return to “Tlön, Uqbar, Orbis Tertius” in order to light upon its extremely suggestive discussion of materialism and the nature of existence, which pertains directly to Schrödinger’s wave function. Borges’ narrator cites the words of a certain Tlönian heresiarch, who attempts to subvert the Tlönian dogma that whatever cannot be seen likewise cannot exist.

*On Tuesday, X is walking along a deserted road and loses nine copper coins. On Thursday, Y find fours coins in the road, their luster somewhat dimmed by*
Wednesday’s rain. On Friday, Z discovers three coins in the road. Friday morning X finds two coins on the veranda of his house.

From this story the heresiarch wished to deduce the reality – i.e., the continuity in time – of those nine recovered coins. (CF 75)

While the connection of this anecdote to the wave function is not immediately apparent, referring to what Floyd Merrell has written about this section of the story will clarify this link.

The coins supposedly having existed from the instant they were lost to the moment of their rediscovery would imply their continuous existence – the view of classical Western science – which was intuitively impossible for the Tlönians. They believed the coins ceased to exist once they were lost, i.e., unperceived, and popped into existence upon their being found. Idealism ruled – and the furniture of Tlön was presumably discontinuous: being was only upon being perceived. Or, in the quantum theoretical sense, a set of “superposed” waves is actualized into one of a number of probable events upon interaction. (Merrell 159)

In his characteristically poetic manner, Merrell has restated the wave function in Borgesian terms; the Tlönians, who equate perceptibility with existence and, likewise, imperceptibility with nonexistence, appear to live, always, in the same paradigm as Schrödinger’s cat. The “parable of the nine coins” distills the entire Tlönian conception of reality into extremely basic terms, demonstrating that all possibilities exist simultaneously, suspended in a probability wave until such a time as they are actualized, either through observation or some other version of verification. In this way, as Merrell agrees, the coins both exist and do not exist: “the Tlönians predicament is, however baffling to our mind-set, that of Schrödinger’s cat and the inconceivable behavior of the quantum world.” (Merrell 160)

These paltry few coins are not the only sign of Borges’ employment of superposition in this story, however. As if to frame this smaller section, we find at the end of the story a distinct possibility that Tlön – this imagined, fictional parallel universe – may be coming to be superposed with our own, tangible world.

Contact with Tlön, the habit of Tlön, has disintegrated this world… A scattered dynasty of recluses has changed the face of the earth – and their work continues.
If my projections are correct, a hundred years from now someone will discover the hundred volumes of The Second Encyclopedia of Tlön. At that, French and English and mere Spanish will disappear from the earth. The world will be Tlön. (CF 81)

The more that the possibility of Tlön comes to be contemplated by humanity, the more that its wave function must be seen as uncollapsed (e.g. possible) and superposed with that of our own world. While perhaps simply intended by Borges as a moment of sly, meta-textual humor, this dilemma also has the function of reducing the reader’s own experienced reality *ex libris* to one of many other probable superposed states – if Tlön is as probable as Borges’ narrator’s world, can Borges’ fiction come to be overlaid onto our own? Is its wave function simply awaiting an external observer to verify and collapse it? If so, we might boldly look upon Borges’ reader as carrying the crucial role of actualizing a specific state out of all those superposed, just as the scientist in Schrödinger’s cat dilemma. The reality that would subsequently be brought into being is certainly problematic, although no less “real.” Allen Thiher, in a study of the interrelationship between fiction and science in the Modernist era, contributes the following commentary on Tlön:

This fiction dramatizes the proposition that a well-wrought encyclopedia might replace all other systems of knowledge, and hence all other imagined universes, through the power that the encyclopedia has to confer order on that metaphysical dream called “reality.” The imagined encyclopedia describing a unique fictional cosmos, contrived by men desirous of greater order than can be found in their usual seedy universe, begins to supplant all other representations. The new encyclopedia and its orderings impose upon themselves as “reality.” If coherence is a fundamental criterion for accepting that a proposition is knowledge, then it is logical that an imaginary order may well be deemed superior to the universe known through fragmented sciences – as the narrator of “Tlön, Uqbar, Orbis Tertius” observes in looking at recent history. (Thiher 239-240)

By creating a fictional order that seems more probable than the existing natural order of our own universe – thereby complicating the coherence of reality – Borges has, deliberately or not, toyed with superimposing successive probability waves. He has superposed the fictional and the real, leaving it up to the reader to bring one of these states into being through observation.
Calvino, too, deals with these themes of probability, transferability and superposition in a story entitled “The Chase,” published in *T zero*. An exceptionally tense description of the narrator’s obstructed flight from his would-be murderer in dense city traffic, this story slowly metamorphoses the hunted into the hunter, eventually equating the two in a moment of probabilistic universality. As the narrator’s car lurches forward incrementally, so does that of his assailant, while they both continuously attempt to calculate the probability of making the next green light – waiting, in Schrödingerian terms, for the waveform to collapse into one outcome or another. “In short,” the narrator laments, “I and the man commissioned to kill me are as if immobilized in a space that moves on its own, we are soldered to this pseudo-space which breaks up and re-forms and on whose combinations our fate depends.” (Calvino 116) The probabilistic nature of this situation is explicitly stated, which strengthens the proposed link with quantum wave functions.

After a brief, motionless moment of optimism in which the narrator imagines the case of eventually ending up *behind* his pursuer, the drama continues: “If, however, the number of these interval-cars were to increase or diminish then our pursuit would once again be a real pursuit… both eventualities have some likelihood of taking place.” (ibid. 121) The equivalence of multiple possibilities and their immediate inability to be verified is, again, a direct connection with Schrödinger. In fact, a later statement by the narrator essentially dictates the basis of quantum probability:

It is the bodies therefore that determine the surrounding space, and if this affirmation seems to contradict both my experience and my pursuer’s – since the two of us can’t determine anything at all, neither space to flee in nor space to pursue in – it is because we are dealing with a property not of single bodies but of the whole complex of bodies in their reciprocal relationships, in their moments of initiative and of indecision, of starting the motor, in their flashing of lights and honking and biting nails and constant angry shifts of gear: neutral, first, second, neutral; neutral, first, second, neutral… In short, each car is in the center of a
system of relationships which in practice is the equivalent of another, that is, the cars are interchangeable, I mean the cars each with its driver inside; each driver could perfectly well change places with another driver, I with my neighbors and my pursuer with his.” (ibid. 122-3)

With this, Calvino is beginning to extend the equivalence of possibilities into the potential parity between other objects and people, which leads us into a further assumption of universality and superposed states of probability. The lines between “self” and “other” begin to blur: “On thinking it over, I deduce that if all cars are involved in pursuits, the pursuing property would have to be commutative, and anyone who pursues would have to be in his turn pursued and anyone who is pursued would also be pursuing.” (ibid. 125)

As the narrator’s pursuer moves into position directly behind him, these theorizations reach a fever pitch, culminating in a not-too-unexpected merging of the roles of pursuer and pursued. With the probability wave’s collapse imminent, the narrator submits to conjecture.

Now that the signal is turning green and it is probable that in this very period of free movement I can succeed in pushing my way into the intersection where my fate will be decided, I realize the decisive element is not behind me but in my relationship with the man ahead of me. So, the only significant alternative is whether my condition of pursued man is destined to remain terminal and asymmetrical (which would seem proved by the fact that in the relationship with my pursuer I am unarmed) or if I too in my turn am a pursuer. (ibid. 126)

At that, the narrator reaches into his glove box, finds a loaded pistol, fires a lethal shot at the man occupying the car in front of him – now (and always) his sworn enemy – and speeds into a cross street, only to be once again caught in the tide of traffic. We might confidently assume that this cycle is intended to continue endlessly, with all men playing all roles and, simultaneously, existing as both pursued and pursuer, both alive and dead. Kerstin Pilz has stated that “The Chase”

…is about a car chase and the narrator’s calculations regarding the probabilities of his pursuer catching up with him as they move through dense traffic. His hypotheses lead him to the unsatisfactory conclusion that the distinction between
the pursuer and the pursued, the subject and the object is blurred… This conclusion points to the paradox of Calvino’s efforts to escape the limitations of an anthropomorphic vision of the world and his awareness of its impossibility, since any attempt to speak about the world, even in the abstract terms of formal logic, will always be subjective. (Pilz 44)

While Pilz is quite correct in a literary sense, we will take a different, more quantum-minded approach: like Schrödinger’s unlucky feline, Calvino’s narrator and his pursuer exist in a state of superposition until their true natures are manifested in an observable way – in other words, verified. Until that moment, just as the cat is both alive and dead, both men are both pursued and pursuer; the unfortunate man in front of the narrator is both guilty and innocent. If we imagine their varied and intersecting trajectories and personal storylines as a set of equally probable, un-collapsed waveforms, it becomes clear that no other story in the oeuvres of Borges and Calvino serves better to represent this idea.

**Quantum Entanglement – Coincidence, Simultaneity and Specularity**

We have seen that quantum effects on matter, space and time open the door to uncertain and unpredictable (and sometimes inexplicable) outcomes. An extension of these outcomes is known as *action at a distance*, which describes the phenomenon of two objects interacting with each other without any physical contact in space. An understandably skeptical and fearful Einstein famously called this action “spooky,” an adjective that has remained attached to subsequent explanations of “quantum entanglement,” as this action has come to be known in modern quantum theory. Brian Greene provides the most approachable introduction to this concept:

It turns out, contrary to locality, that something we do over here (such as measuring certain properties of a particle) can be subtly entwined with something that happens over there (such as the outcome of measuring properties of another distant particle), without anything being sent from here to there… This sounds
like voodoo; Einstein, who was among the first physicists to recognize – and sharply criticize – this possible feature of quantum mechanics, called it “spooky.”… This means that space cannot be thought of as it once was: intervening space, regardless of how much there is, does not ensure that two objects are separate, since quantum mechanics allows an entanglement, a kind of connection, to exist between them. (Fabric 80)

In essence, one particle can have an effect on another even if they are too far apart to communicate at light speed – this means, of course, that there must be some other unknown means by which particles communicate, a notion that disturbs modern science at its core. Brian Clegg, another astrophysicist who has written prolifically on quantum effects, describes the same phenomenon in his book on the subject:

At [the] quantum level, it is possible to link particles together so completely that the linked objects (photons, electrons, and atoms, for instance) become, to all intents and purposes, part of the same thing. Even if these entangled particles are then separated to opposite sides of the universe, they retain this strange connection. Make a change to one particle, and that change is instantly reflected in the other(s) – however far apart they may be. (Clegg 2)

Later in his book, Clegg goes on to add that “entanglement provides a secret link, an unfathomable bond between two particles.” (Clegg 90) All of this reinforces the idea that quantum theory suggests a mystical, almost anagogical aspect of reality in which two particles or objects have the potential to act upon each other without a known means of contact. In the case of quantum entanglement, in fact, these particles and objects mirror each other so closely that one effectively becomes the other at another location in space. Two particles, separated by unfathomable eons of space-time, can achieve perfect specularity.

All of this conceptualization is, of course, understandably nebulous without a description of the experimental verification process that led to its discovery. Fortunately, Clegg goes into such detail in his book:

Einstein and his colleagues imagined a particle breaking down into two others, a common enough occurrence in quantum physics. The two new particles shoot off
in opposite directions, each with an equal and opposite momentum just as Newton had foretold should happen. The initial particle wasn’t moving, so the momentums of the two new particles had to cancel out, because you can’t produce momentum out of nowhere. What’s interesting about this setup is that each particle can tell us something about the other. Measure the distance one has traveled and you know how far the other has gone. Measure one particles momentum and you know the momentum of the other… Say we measure the momentum of the first particle. Because of the neat symmetry of the experiment, we immediately also know the momentum of the second particle. But according to quantum theory, neither particle had a fixed momentum until the first moment the particle was measured. Now, immediately, we know the value for both particles, however far apart they have traveled. At this stage comes the clincher. At the instant we measured the first particle’s momentum, how did the second particle “know” what momentum it should have? If its momentum was, until that moment, just a range of probabilities rather than a particular fixed value, what caused it to jump to a particular actual momentum – the same momentum as the first particle, but in the opposite direction?... It would seem that only by instant action at a distance that one particle could influence the other. After all, we could wait as long as we like before making the measurement, so the two particles could be light-years apart. Assuming (as Einstein did) that it’s impossible for any communication between the two instantaneously, the only deduction we can make is that the second particle already had that momentum.” (Clegg 34-35)

The conclusion granted by this experiment, then, is not that momentum is transmitted from one particle to another, but rather that two entangled particles already have the same momentum.

Because of the probabilistic nature of quantum theory, the value of this momentum is unknown to us until the moment of measurement, but despite our own ignorance the experiment appears to prove that a mirror-like symmetry between the two particles existed prior our observation.

Bundling the most creative theorizations of Einstein, Heisenberg and Schrödinger into one concept, quantum entanglement represents the scientific equivalent of literary specularity or “mirroring.” Aside from demonstrating once again the shared conceptual foundations of science and fiction, this observation also returns us to the main subjects of our study; Borges and Calvino, as masters of the form, deliver numerous examples of what we might playfully deem “literary entanglement.”
Most of Borges’ “entangled pairs” appear in *The Aleph*, a familiar collection of short stories that rely heavily on the device of specularity – more so, in fact, than the rest of his oeuvre. “The Theologians,” for example, contains two characters who, despite living as sworn enemies, are eventually shown to be the entangled equivalent of one another. The clerics Aurelian of Aquileia and John of Pannonia – each racing against the other to refute a heresy involving the circularity of time – could not be more different from the start. Aurelian, in his refutation, prefers “vast labyrinthine periods, made impassable by the piling-up of clauses upon clauses.” (CF 202) John, on the other hand, provides a discourse that the narrator describes as “almost ludicrously brief.” (ibid. 203) Borges has inserted signs of equivalence and specularity into John’s treatise, though – we are told that “John’s treatise was limpid, universal; it seemed written not by a particular person, but by any man – or perhaps all men.” (ibid. 203) Eventually, the Roman leaders of the Church choose John’s argument as the official stance on the heresy, much to Aurelian’s dismay.

Their feud continues; the narrator tells us that “Aurelian wrote not a word that was not aimed, however unconfessably, at besting John.” (ibid. 203) Heresy arises again, this time much more virulently: “It seemed to be everywhere; people said that in the diocese of Britain crucifixes had been turned upside down and in Cæsaria the image of the Lord had been supplanted by a mirror.” (ibid. 204) The mirror as the symbol *par excellence* of specularity once again alerts the reader to this theme, reinforcing the overarching entanglement of the two antagonists in the tale. Soon after, we encounter further mirroring: “In the hermetic books,” the narrator states, “it is written that ‘things below are as things above, and things above as things below’; the Zohar tells us that the lower world is a reflection of the higher.” (ibid. 204) Aspects
of this heresy seem to therefore point directly at a concept akin to that of quantum entanglement, joining couples and groups of objects and ideas in apparent symmetry.

Aurelian, in penning his response to this heresy, is suddenly seized by writer’s block.

After a brief pause, he is seized by a compulsion:

Then suddenly a sentence of twenty words came to his spirit. With joy he wrote it on the page; immediately afterward, he was disturbed by the sense that it was someone else’s. The next day, he remembered: he had read it many years ago in the Adversus Annulares, composed by John of Pannonia. (ibid. 206)

With the words of his double flowing through him, Aurelian submits his response to Rome, including a caveat denouncing John of Pannonia for heresy. John is subsequently tried, convicted and condemned to be burned at the stake. Under an obligation to attend the execution, Aurelian witnesses the death of his double, and the full scope of their entanglement is made apparent:

The pyre was about to consume [John], when Aurelian screwed up his courage to raise his eyes. The fiery gusts fell still; Aurelian saw for the first and last time the face of the man he hated. It reminded him of someone, but he couldn’t quite remember whom. Then, the flames swallowed him; he screamed and it seemed as though the fire itself were screaming. (ibid. 207)

Years pass, and Aurelian, never forgetting his role in John of Pannonia’s execution, moves across the Earth, eventually settling in Hibernia. His end (and its aftermath) is in perfect symmetry with that of John;

In Hibernia, in one of the huts of a monastery besieged by forest, he was surprised one night, toward dawn, by the sound of rain. He recalled a Roman night when that same punctilious sound had surprised him. At high noon, a lightning bolt set the trees afire, and Aurelian died as John had. The end of the story can only be told in metaphors, since it takes place in the kingdom of heaven, where time does not exist. One might say that Aurelian spoke with God and found that God takes so little interest in religious differences that He took him for John of Pannonia. That, however, would be to impute confusion to the divine intelligence. It is more correct to say that in paradise, Aurelian discovered that in the eyes of the unfathomable deity, he and John of Pannonia (the orthodox and the heretic, the abominator and the abominated, the accuser and the victim) were a single person. (ibid. 207)
Here, the case for entanglement between John and Aurelian is explicitly proven. Borges’ words do not simply suggest that these men were “similar,” or that their shared demise was coincidental – on the contrary, we are told unequivocally that they “were the same person.” Just as an entangled pair of particles share the same momentum and rotation, so too were John and Aurelian so indistinguishable from one another that God regarded them as one, single person.

This same technique is employed more indirectly in a rather obtuse tale from *The Aleph*: the flatly-named “Story of the Warrior and the Captive Maiden.” It begins with the brief biography of a 6th-century Lombard warrior named Droctulft, who became so enamored with the city of Ravenna that he abandoned his own culture and died passionately defending his new home. The tale abruptly shifts to that of Borges’ own grandmother, “an Englishwoman torn from her country and her people and carried to this far end of the earth [i.e. Argentina].” (ibid. 210) Borges’ grandmother encounters a woman dressed in indigenous Indian garb, but with curiously blonde hair. Speaking with her, it is revealed that she, too, had been transplanted in Argentina from England as a child, only to be taken from her family in an Indian raid and subsequently raised by the tribe. Borges’ grandmother is moved by this woman, who had eventually become the consort of a minor chieftain and had borne his children.

Moved by outrage and pity, my grandmother urged her not to go back. She swore to help her, swore to rescue her children. The other woman answered that she was happy, and she returned that night to the desert. Francisco Borges was to die a short time later, in the Revolution of ’74; perhaps at that point my grandmother came to see that other woman, torn like herself from her own kind and transformed by that implacable continent, as a monstrous mirror of her own fate. (ibid. 210-11)

The case for entanglement in this story is made soon after by the narrator.

Thirteen hundred years and an ocean lie between the story of the life of the kidnapped maiden and the story of the life of Droctulft. Both, now, are irrecoverable. The figure of the barbarian who embraced the cause of Ravenna, and the figure of the European woman who chose the wilderness – they might
seem conflicting, contradictory. But both were transported by some secret
impulse, an impulse deeper than reason, and both embraced that impulse that they
would not have been able to explain. It may be that the stories I have told are one
and the same story. (ibid. 211)

Borges is able to equate these tales on the basis of not only their parallel narratives, but also
through a shared “secret impulse”; can this invisible means of connection not be the same “secret
link” or “unfathomable bond” that Brian Clegg has invoked in his description of quantum-
entangled particles? That this connection is “deeper than reason” – e.g., that it cannot be
explained logically (or scientifically) – is only further evidence that the equivalence between
literary specularity and quantum entanglement is significantly credible.

The specular images provided by Borges continue in a fiction entitled “Deutches
Requiem,” which recounts the life and death of Otto Dietrich zur Linde, a Nazi concentration
camp officer. A cruel and severe man, zur Linde applies a cold, philosophical approach to his
torture of the Jews in his camp, most notably “the famous poet David Jerusalem.” (ibid. 232)

After praising the efficacy and beauty of Jerusalem’s poems, zur Linde goes on explain how he
governed this man in the camp.

I was severe with him; I let neither compassion nor his fame make me soft. I had
realized many years before I met David Jerusalem that everything in the world
can be the seed of a possible hell; a face, a word, a compass, an advertisement for
cigarettes – anything can drive a person insane if that person cannot manage to
put it out of his mind. Wouldn’t a man be mad if he constantly had before his
mind’s eye the map of Hungary? I decided to apply this principle to the
disciplinary regimen of our house, and… In late 1942, Jerusalem went insane; on
March 1, 1943, he succeeded in killing himself. (ibid. 232)

What immediately follows this sadistic confession is striking in its opposition to what has been
said – zur Linde, in a psychologically-minded soliloquy, begins to see himself in the person of
David Jerusalem:

I do not know whether Jerusalem understood that if I destroyed him, it was in
order to destroy my own compassion. In my eyes, he was not a man, not even a
With this fledgling specularity between the guard and the prisoner established, Borges begins to expand this entanglement to include all men and all nations, as the Third Reich begins to fall around zur Linde.

Hitler thought he was fighting for a nation, but he was fighting for all nations, even for those he attacked and abominated. It does not matter that his ego was unaware of that; his blood, his will, knew. The world was dying of Judaism, and of that disease of Judaism that is belief in Christ; we proffered it violence and faith in the sword. That sword killed us, and we are like the wizard who weaves a labyrinth and is forced to wander through it till the end of his days, or like David, who sits in judgment on a stranger and sentences him to death, and then hears the revelation: Thou art that man. (ibid. 233-4)

Though this statement reeks of odious prejudice and revisionist perspective, Borges’ intentionally despicable narrator has established an entanglement between the killer and the killed, the villain and the hero. The last paragraph of the story has zur Linde gazing, fittingly, into a mirror, Borges’ perennial symbol for equivalence and one that we have now come to note repeatedly in our analysis of literary entanglement. To zur Linde, he and David Jerusalem are the same person, just as Germany is any other country and the Nazi ideology is any other ethos. A distasteful merging of identity, to be sure, but one that effectively highlights an unfortunate consequence of this abstract concept.

While all of these examples have come from the same collection of stories, there is an earlier example of literary entanglement (as we have called it) in Borges’ body of work: “The Shape of the Sword,” found in Artifices (1944). In it, the narrator (“Borges,” as usual) comes to meet an Irishman with a ghastly facial scar who has taken up residence in Argentina. The bulk of the story is a recounting of how he obtained this scar during the war for Irish independence. The narrator saves an ardently vociferous, Communist rebel – John Vincent Moon – from death at the
hands of a soldier, only to discover that the fiery but bookish revolutionary is frightened and useless in battle. Their specularity is shown almost immediately: “It was then that I realized that he was a hopeless coward. I clumsily told him to take care of himself, then left. I was embarrassed by the man and his fear, shamed by him, as though I myself were the coward, not Vincent Moon.” (ibid. 141) Within days, the Irishman overhears Moon on the telephone, surreptitiously arranging for the Irishman’s arrest and his own guaranteed safety. In a fit of anger, the Irishman attacks Moon, and their equivalence as an entangled pair becomes explicit:

Moon knew the house well, every bit as well as I. Once or twice I lost him, but I managed to corner him before the soldiers arrested me. From one of the general’s suits of armor, I seized a scimitar, and with that steel crescent left a flourish on his face forever – a half-moon of blood. (ibid 142)

The befuddled narrator of the story asks for clarification:

“And Moon?” I asked. “What became of Moon?” “He was paid his Judas silver and he ran off to Brazil. That evening, in the city square, I saw a dummy shot by a firing squad of drunks.” I waited vainly for the rest of the story. Finally, I asked him to go on. A groan made his entire body shiver; he gestured, feebly, gently, toward the curving, whitish scar. “Do you not believe me?” he stammered. “Do you not see set upon my face the mark of my iniquity? I have told you the story this way so that you would hear it out. It was I who betrayed the man who saved me and gave me shelter – it is I who is Vincent Moon.” (ibid 142)

Admittedly, the existence of a true entangled pair is less obvious in this tale than in the others – rather than existing as identical analogues of the same person, it seems that this man and his double may have merely switched places. The only clue to the contrary is the Irishman’s having witnessed the mock execution in the city square, despite his double having already left for Brazil – this could suggest that both men had witnessed all of each others’ experiences, which would require them to be entangled. In its brevity, this story is less satisfying in terms of proving our hypothesis, though it is nonetheless relevant and provocative.
There are still other examples of entanglement in Borges’ works, but rather than repeat the same analysis on what would amount to identical narrative structures we will instead be better served by moving on to examples that can be found in Calvino’s fictions. The most compelling of these comes from a minor work, *The Castle of Crossed Destinies*, in the form of a combinatorial novella that narrates a frantic attempt by multiple mute narrators to tell overlapping stories. Since they cannot speak, they are limited to communicating by way of judicious selections from a single deck of tarot cards.

The square is now entirely covered with cards and with stories. My story is also contained in it, though I can no longer say which it is, since their simultaneous interweaving has been so close. In fact, the task of deciphering the stories one by one has made me neglect until now the most salient peculiarity of our way of narrating, which is that each story runs into another story, and as one guest is advancing his strip, another, from the other end, advances in the opposite direction, because the stories told from left to right or from bottom to top can also be read from right to left or from top to bottom, and vice versa, bearing in mind that the same cards, presented in a different order, often change their meaning, and the same tarot is used at the same time by narrators who set forth from the four cardinal points. (Calvino 41)

What follows from this point is a chaotic hodgepodge of half-told stories, each blending into the others and lending an atmosphere of generalized confusion. This chapter serves as a conclusion to the first “act” of the book, and so it is fitting that the cards that had served to organize and motivate the initial chapters might now be complicated by an inevitable increase in entropy. The chapter concludes shortly after the narrator struggles to logically work out his own tale’s resolution, which has become entangled with those of the others.

Surely my own story is also contained in this pattern of cards, my past, present, and future, but I can no longer distinguish it from the others. The forest, the castle, the tarots have brought me to this point, where I have lost my story, confused it in the dust of the tales, become freed of it. What is left me is only the manic determination to complete, to conclude, to make the sums work out. (ibid. 46)
There could be perhaps no other way to end this tale, or this book; the experiment of narrating through random combinatorial selection provides enormous potential, but almost no logical structure. Regardless of this limitation, however, Calvino achieves a major success in equating the story of one with the stories of all others, essentially proving their entanglement by way of their shared probabilities. In *The Castle of Crossed Destinies*, the reader is simply not fortunate enough to witness the eventual collapse of the probability wave, and as such the stories therein all remain unverified and, therefore, possible.

A final example of literary entanglement is found in Calvino’s most famous work, *Invisible Cities*. The city of Zobeide, hewn from a dream shared by many, equates all of its builders:

> Men of various nations had an identical dream. They saw a woman running at night through an unknown city; she was seen from behind, with long hair, and she was naked. They dreamed of pursuing her. As they twisted and turned, each of them lost her forever. After the dream they set out in search of that city; they never found it, but they found one another; they decided to build a city like the one in the dream. (Calvino 45)

At slightly more than one page in length, the description of Zobeide does not provide a large amount of detail with which to theorize – however, it seems that the city itself can be conceptualized as a staging ground for entangled pairs or groups. From a different angle, we might alternately consider that it is not the builders but their *dreams* that are entangled; if a dream is the result of the processes of a select portion of the brain, perhaps the whole man need not be entangled – after all, particles as small as electrons built the case for quantum entanglement in the first place. It must be stated that Calvino did not routinely employ the same technique of specularity that Borges did; here, however, we can definitively see a similar concept in action.
To conclude our discussion of quantum and literary entanglement, we will briefly touch upon one of its most intriguing possibilities: teleportation. Evergreen fodder for science fiction, teleportation has recently been theorized to be technically possible through the mystery of entanglement, albeit with certain limitations. Brian Greene explains:

Remember, two entangled particles, say two photons, have a strange and intimate relationship. While each has only a certain probability of spinning one way or the other, and while each, when measured, seems to “choose” randomly between the various possibilities, whatever “choice” one makes the other immediately makes too, regardless of their spatial separation… Quantum entanglement could be used for quantum teleportation. You might not be able to send a message at a speed greater than that of light, but if you’ll settle for slower-than-light teleportation of a particle from here to there, entanglement’s the ticket. (Fabric 442-3)

While promising at the subatomic level, the prospects for teleporting larger or more complex structures are less optimistic:

Can we ever use teleportation on solid objects with structure – perhaps even life? Even for a single particle this is a nontrivial challenge. Teleportation experiments to date have focused on a single property of a particle – its spin, for instance – but to truly teleport a particle it would be necessary to teleport all the properties separately. (Clegg 212)

Complex structures could therefore be potentially teleported property-by-property, which is not wholly disheartening for inanimate objects. For living things, though, this would be absolutely lethal: “To be teleported, every atom in your body would have to lose its quantum uniqueness. It would involve nothing less than total disintegration. Yes, the outcome would be a perfect copy with all your memories and personality, but would it be you?” (ibid. 218) The entangled literary pairs we have seen in our analysis had little or no difficulty in maintaining the “you” to which Brian Clegg is referring, but in reality this would be a philosophical quandary of the highest order. Nonetheless, such difficulties do not nullify the value of the dialogue between science and fiction that is being undertaken. Clegg seems to agree, echoing so many other scientists and philosophers that have already been cited in this study:
This doesn’t make all speculation worthless, though. Not only can it produce new and wonderful ideas – arguably all modern physics originates from a handful of vibrant speculations that challenged traditional science at the start of the twentieth century – but it can result in a very healthy shaking up of what can otherwise be entrenched and self-satisfied thinking. (ibid. 223)

By not only considering but also manipulating and testing the impossible – in both scientific and literary arenas – humanity increases its chances of achieving creative and unexpected advancements in every field.

**Multiple Dimensions and Multiverses**

While quantum entanglement has presented a strong basis for comparison with literary specularity, the concept of the multiverse will in turn allow for a discussion of the presence of ramifying time and physically-adjacent paradigms in fiction. Borges’ “The Garden of Forking Paths” will stand as the most well-known example of this analysis, supplemented by Calvino’s story “T zero” and his novel *Se una notte d’inverno un viaggiatore*… In each of these works, the reader is presented with a vision of the potentiality inherent in choice; as each decision is made, all other possible outcomes to that decision branch out into divergent directions, with each existing separately from the other. This image is directly in line with the modern scientific concept of the multiverse, which theorizes that there exists the actual potential for an infinity of universes, each the embodiment of some slightly different arrangement of particles. Through this theory, every decision that has ever been made would have as an abode its own, unique universe.

We can begin with some background on multiverse theory, of course – Brian Greene acknowledges the creative fecundity of this concept:

[An] early version of parallel universes resonated with themes of separate lands or alternative histories that were being explored in literature, television, and film, creative forays that continue today. (My favorites since childhood include *The Wizard of Oz, It’s a Wonderful Life*, the Star Trek episode “The City of the Edge
of Forever,” the Borges story “The Garden of Forking Paths,” and, more recently, *Sliding Doors* and *Run Lola Run.*) Collectively, these and many other works of popular culture have helped integrate the concept of parallel realities into the zeitgeist and are responsible for fueling much public fascination with the topic. (Hidden 6-7)

Based on what Greene has stated, we could make the assertion that it is science, in actuality, that is indebted to fiction, due to fiction’s role in generating such a cultural curiosity and public awareness of what amounts to a maddeningly difficult scientific theory. Art and literature, in their freedom from the burden of verifiability, can perform thought experiments using ideas taken from science even when science itself cannot. The themes and functions of these two disciplines are intertwined – science and literature are two elements of one apparatus that allows us to better understand the cosmos.

In *The Hidden Reality*, Brian Greene focuses specifically on multiverse theory, working from its origins through to the current criticisms against it. He admits, late in the work, that this theory’s basis is fundamentally a creative theorization:

> Is it scientifically justifiable to speak of a multiverse, an approach that invokes realms inaccessible not just in practice but, in many cases, even in principle? Is the notion of a multiverse testable or falsifiable? Can invoking a multiverse provide explanatory power of which we’d otherwise be deprived? If the answer to these questions is no, as detractors insist is the case, then multiverse proponents are assuming an unusual stance. Nontestable, nonfalsifiable proposals, invoking hidden realms beyond our capacity to access – these seem a far cry from what most of us would want to call science. (ibid. 189)

After laying out such a disturbing case for the “scientific-ness” of multiverse theory, Greene goes on to justify the case for belief, stating that if a theory comes to be accepted as verifiable, the whole theory must be accepted – we cannot cherry-pick the elements that serve us and eschew those that are inconvenient or unexpected. Because of this, the multiverse conjecture falls very much within the bounds of science. Its proposed veracity stems from the tenets of basic science, strangely enough: “Basic physical principles establish that if the cosmos is infinitely
large, it is home to infinitely many parallel worlds – some identical to ours, some differing from ours, many bearing no resemblance to our world at all.” (ibid. 12)

Without delving too deeply into the overwhelmingly complex physics that define multiverse theory, we can briefly analyze how it is to be imagined:

If space is large but finite, we can divide it into a large but finite number of such independent patches. If space is infinite, then there are an infinite number of independent patches. It’s this latter possibility that’s of particular allure… In any given patch the particles of matter (more precisely, matter and all forms of energy) can be arranged in only a finite number of different configurations… This means that conditions in the infinity of far-flung patches – in regions of space like the one we inhabit but distributed through a limitless cosmos – necessarily repeat. (ibid. 33)

Aside from destabilizing the importance of our own universe, this explanation suggests an even more disturbing implication:

Adhering to this perspective, we conclude that if the particle arrangement with which we’re familiar were duplicated in another patch – another cosmic horizon – the patch would look and feel like ours in every way. This means that if the universe is infinite in extent, you are not alone in whatever reaction you are now having to this view of reality. There are many perfect copies of you out there in the cosmos, feeling exactly the same way. And there’s no way to say which is really you. All versions are physically and hence mentally identical… Were you to visit these inexact copies, you’d find some that are barely distinguishable from ours, while in others the differences would range from obvious to exhilarating to shocking. Every decision you’ve ever made is tantamount to a particular particle arrangement. (ibid. 39)

The multiverse, then, annihilates the uniqueness that humans consider a given in their perception of reality, and offers us instead the consolation of existing as only one of a literally infinite series of parallel universes. The psychological effect of contemplating this idea leads us headlong into a literary frame of mind – it is easy to see why writers of science fiction have so often relied on such concepts to mystify audiences.

Physicists have theorized that one way to access a parallel universe would be to carefully harness the space-time warping properties of a black hole – but not just any black hole will do.
Michio Kaku clarifies that only a rotating black hole could potentially provide access without obliterating the traveler.

[Roy] Kerr found… that a massive rotating star does not collapse into a point. Instead, the spinning star flattens until it eventually is compressed into a ring, which has interesting properties. If a probe were shot into the ring from the side, it would hit the ring and be totally demolished… However, if a space probe were shot into the ring from the top or bottom, it would experience a large but finite curvature; that is, the gravitational force would not be infinite. This rather surprising conclusion from Kerr’s solution means that any space probe shot through a spinning black hole along its axis of rotation might, in principle, survive the enormous but finite gravitational fields at the center, and go right through to the mirror universe without being destroyed by infinite curvature. (Hyperspace 226)

While titillating, this possibility currently exists only in theory; human science is nowhere near capable of employing black holes in its endeavors, since there is still so much that we do not know about their properties. Fiction, however, is unfettered – free to pose and visualize, we can look to a number of works by Borges and Calvino for examples (both direct and indirect) of inspiration and experimentation relating to the concepts of multiverses and parallel dimensions.

Borges’ “Pierre Menard, Author of the Quixote” rewrites the history of the classic work normally attributed to Miguel de Cervantes. Borges achieves this through an ingenious thought experiment that probes the limits of authorship and, probably inadvertently, tips into the same territory as the theory of parallel dimensions. His narrator, an associate of the deceased writer Pierre Menard, defends his friend’s oeuvre, listing all of his literary accomplishments and naming one work above all others;

This work, perhaps the most significant writing of our time, consists of the ninth and thirty-eighth chapters of Part I of Don Quixote and a fragment of Chapter XXII. I know that such a claim is on the face of it absurd; justifying that “absurdity” shall be the primary object of this note… Pierre Menard did not want to compose another Quixote, which is surely easy enough – he wanted to compose the Quixote. Nor, surely, need one be obliged to note that his goal was never a mechanical transcription of the original; he had no intention of copying it.
His admirable ambition was to produce a number of pages which coincided—word for word and line for line—with those of Miguel de Cervantes. (CF 90-91)

Two men, then, appear to have organically produced an identical work. Rather than write an anachronistic, analogous work by way of his own experiences, Menard instead planned to live through all of Cervantes’ experiences, thereby achieving the same work at the end of this exercise. Borges’ narrator tells us that, in the end, “the Cervantes text and the Menard text are verbally identical, but the second is almost infinitely richer.” (ibid. 94) While the absurdity of this statement is obviously intended by Borges as wry humor, it also confirms the notion that both authors—Menard and Cervantes—may exist in parallel but separate dimensions. If two ramifications of prior time led to the isolated and organic creation of identical Quixotes, we need only hearken back to Brian Greene’s comments to assert that both Quixotes do exist, albeit in separate universes; universes that, while largely identical, do have different particle arrangements—in this case, the substitution of Cervantes for Menard, and his placement in a different time period. Both situations carry an equal probability of existing in an infinite universe.

Floyd Merrell has commented on Borges’ comprehension of advanced scientific theories such as these, stating that it is “apparent that Borges… takes metaphysical doctrines, scientific theories, and other particular perspectives of the world at face value. Each is a world, none is The World.” (Merrell 9) Without explicit proof that Borges possessed an awareness of parallel dimensions, we can nonetheless claim a sort of convergence to be seen in his works; stories such as “Death and the Compass” and “The Other” demonstrate the same juxtaposition between parallel dimensions or paradigms. In “Death and the Compass,” a game of cat-and-mouse between a detective named Lönnrot and a serial murderer named Scharlach reaches its denouement in the Villa Triste-le-Roy; the villa is described as abounding in “pointless
symmetries and obsessive repetitions.” (CF 153) As if moving through an M.C. Escher painting, “Lönnrot explored the house. Through foyers that opened onto dining rooms and on through galleries, he would emerge into identical courtyards – often the same courtyard. He climbed dusty stairs to circular antechambers; he would recede infinitely in the facing mirrored walls…” (ibid. 153-54) After being ambushed by Scharlach, Lönnrot – who had previously imprisoned Scharlach’s brother, a criminal in his own right – learns that he is the victim of an elaborate trap, in which Scharlach has built a mental “labyrinth” around Lönnrot while he hunted the criminal. The story closes with an image of dual labyrinths: one envisioned by Lönnrot and another by Scharlach; while both exist by virtue of their having been conceived by each of the men, these mazes appear to also exist adjacent to one another, rather than overlaid upon each other. We might take this image to represent a moment of contact between two universes or dimensions – one in which Scharlach is the hunter, and another in which Scharlach is hunted; one universe in which Lönnrot is righteous, and another in which he is a criminal. The diametrically opposed perspectives of these two characters seem to be superposed in space and time, but their equally-probably existence would require them to occupy separate and adjacent universes.

“The Other,” which opens The Book of Sand, presents a similar situation, albeit in a more contemplative and peaceful atmosphere. An aged Borges, taking a break from teaching in Cambridge, Massachusetts, sits on a bench overlooking the Charles River. He is soon joined by another man who seems familiar; after a few carefully selected questions, Borges realizes that he is seated next to himself. “‘In that case,’ I resolutely said to him, ‘your name is Jorge Luis Borges. I too am Jorge Luis Borges. We are in 1969, in the city of Cambridge.’ ‘No,’ he answered in my own, slightly distant, voice, ‘I am here in Geneva, on a bench, a few steps from the Rhone.’” (ibid. 412) The younger Borges believes that this is simply a dream – his dream, to
be precise, while the older Borges more wisely suggests that the two of them may simply be separate manifestations of the same person. Eventually, following a series of attempted proofs of his veracity, the older Borges agrees that he himself may simply exist in the dream of the younger Borges.

We parted without having touched one another... I have thought a great deal about this encounter, which I’ve never told anyone about. I believe I have discovered the key to it. The encounter was real, but the other man spoke to me in a dream, which was why he could forget me; I spoke to him while I was awake, and so I am still tormented by the memory. (ibid. 417)

That these two versions of Borges did not make physical contact is crucial to our own hypothesis – young Borges and old Borges both existed in separate universes (or “branes,” to use the terminology of modern multiverse theories) that were somehow adjacent and visible to each other while remaining physically inaccessible. There is scientific merit to this position; John D. Barrow, in fact, contextualizes this phenomenon as the consequence of a truly infinite cosmos.

We believe that the evolution of life is possible with non-zero probability because it has happened on earth by natural means. Hence, in an infinite universe there must exist an infinite number of living civilizations. Within them will exist copies of ourselves of all possible ages. When each of us dies, there will always exist elsewhere an infinite number of copies of ourselves, possessing all the same memories and experiences of our past lives but who will live on to the future. This succession will continue indefinitely into the future and so in some sense each of us ‘lives’ forever. (Barrow 158)

In an infinite universe, then, there will be infinite versions of everyone and everything, including all ages, places and variations. The fictional component of Borges’ story is manifested more in the actualized contact between two such universes – currently, there is no known way for this event to occur.27

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27 Fittingly, Barrow has also cited Borges’ usage of this phenomenon: “The Infinite Replication Paradox has been a source of fascination to writers as well as to scientists and philosophers. Jorge Luis Borges, the great Argentinian writer of short stories, was always fascinated by the possibilities it created.” (Barrow 166)
While the tales that we have examined so far can be linked to multiverse theory in a largely abstract or indirect sense, there are two additional stories by Borges that present even more compelling cases for comparison with multiple/parallel universes. The first of these, “The Writing of the God,” will hew closely to what Brian Greene has referred to as a “holographic universe”:

Reality – not its mere shadow – may take place on a distant boundary surface, while everything we witness in the three common spatial dimensions is a projection of that faraway unfolding. Reality, that is, may be akin to a hologram… Arguably the strangest parallel world entrant, the holographic principle envisions that all we experience may be fully and equivalently described as the comings and goings that take place at a thin and remote locus… A version of Plato’s shadow world – a parallel but thoroughly unfamiliar encapsulation of everyday phenomena – would be reality.” (Hidden 272)

Such specularity is not out of place in Borges’ oeuvre, as was shown in the preceding chapter; incidentally, a reflection of notion can also be found in Calvino’s Invisible Cities, in a city called “Valdrada”:

Thus the traveler, arriving, sees two cities: one erect above the lake, and the other reflected, upside-down. Nothing exists or happens in the one Valdrada that the other Valdrada does not repeat, because the city was so constructed that its every point would be reflected in its mirror, and the Valdrada down in the water contains not only all the flutings and juttings of the facades that rise above the lake, but also the rooms’ interiors with ceilings and floors, the perspective of the halls, the mirrors of the wardrobes. (Calvino 53)

Greene’s further description of holographic multiverses echoes what is seen in this passage from Calvino, and paves the way for an analogous analysis of Borges’ “The Writing of the God”:

For black holes, we found that the link between information and surface area goes beyond mere numerical accounting; there’s a concrete sense in which information is stored on their surfaces… since the information required to describe physical phenomena within any given region of space can be fully encoded by data on a surface that surrounds the region, then there’s reason to think that the surface is where the fundamental physical processes actually happen. Our familiar three-dimensional reality… would then be likened to a holographic projection of those distant two-dimensional physical processes. If this line of reasoning is correct, then there are physical processes taking place on some distant surface that, much
like a puppeteer pulls strings, are fully linked to the processes taking place in my fingers, arms, and brain as I type these words at my desk. Our experiences here, and that distant reality there, would form the most interlocked of parallel worlds. Phenomena in the two – I’ll call them Holographic Parallel Universes – would be so fully joined that their respective evolutions would be as connected as me and my shadow. (Hidden 298-9)

In “The Writing of the God” (alternately translated as “The God’s Script” in some cases), Borges narrates the story of Tzinacán, a priest of the Aztec god Qaholom, who has been imprisoned by the conquering Spanish. He is trapped in a circular cell, with a stone wall dividing it into two halves; in the other half dwells a jaguar, which Tzinacán can make out through a small metal grate for just a few seconds a day, whenever his jailer delivers food and floods the chambers with light. To pass the time until his inevitable death, the priest attempts to remember all that he has ever known – in essence, to re-order himself, piece by piece. Eventually, he recalls a legend of Qaholom, one that recounts the god’s having hidden a magical phrase somewhere in the world. This phrase has the power to actualize the apocalypse and free Tzinacán from both his imprisonment and his life. After long meditations and intervening dreams, the priest is able to see a message written in the stripes of the jaguar – “It is a formula of fourteen random (apparently random) words,” he says, “and all I would have to do to become omnipotent is to speak it aloud.” (CF 253) But just as he gains the means to end both the world and his torture, he loses himself in the fullness and unity of the god, Qaholom. Tzinacán the man, it would seem, no longer exists.

While one critical aspect of this tale is indubitably the idea that, in experiencing the fullness of the universe, one must cease to differentiate oneself from all others, there is another element that will draw us back into our discussion of the holographic multiverse. Jerry Varsava has noted a particularly suggestive moment: “Tzinacán, the magician of the pyramid of Qaholom, in an epiphanic moment experiences the ineffable for which, he tells us, such “poor
and ambitious words” as “all, world, universe” serve as mere “shadows of simulacra.” (Varsava 193) We cannot speak of simulacra, of course, without invoking Jean Baudrillard (and, perhaps, Plato before him); that “all, world, universe” may be nothing more than a hologram of a distinct, separate universe or multiversal region is a concept that can be clearly excavated from Baudrillard’s *Simulacra and Simulation*.

If… the universe is that of which there is no double, no equivalent in the mirror, then with the hologram we are already virtually in another universe: which is nothing but the mirrored equivalent of this one. But which universe is this one? The hologram… gives us the feeling, the vertigo of passing to the other side of our own body, to the side of the double, luminous clone, or dead twin that is never born in our place, and watches over us by anticipation. The hologram, perfect image and end of the imaginary… The universe itself, taken globally, is what cannot be represented, what does not have a possible compliment in the mirror, what has no equivalence in meaning (it is as absurd to give it a meaning, a weight of meaning, as to give it weight at all). Meaning, truth, the real cannot appear except locally, in a restricted horizon, they are partial objects, partial effects of the mirror and of equivalence. (Baudrillard 106-108)

It is this “restricted horizon” that is transcended by Tzinacán by way of spiritual communion with a supernatural essence – pure fiction, in other words. As a universe is, by definition, that which has no double, we can perceive Qaholom’s phrase to be the “true” universe and Tzinicán’s reality (and ours) to be merely a projection or hologram of that greater reality. The link to modern physics’ holographic multiverse theory is therefore not tenuous.28

“The Garden of Forking Paths” is arguably one of Borges’ most famous stories, and certainly the one most cited in popular scientific literature. It is most commonly linked with a modern physics hypothesis by Hugh Everett III that has come to be known as the “Many-Worlds Theory” (formally entitled the “Many-Worlds Interpretation of Quantum Mechanics”), which resolves the difficulty of probability waveform collapse through what amounts to the successive

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28This same holographic principle can also be seen in partial form in a much later story by Borges entitled “There Are More Things,” a horror-themed tale in the style of H.P. Lovecraft. Invoking the evergreen trope of transfinite numbers, it details the events surrounding the narrator’s encounter with an otherworldly abomination – the reflection of some “secret regions of astronomy or time” – in an abandoned house. (CF 442)
and exponential bifurcation of potentialities into equal, distinct and separate realities, or “worlds.” Brian Greene provides a bit of background on this concept:

Hugh Everett’s] analysis, which focused on a gaping hole that [Niels] Bohr, the grand master of quantum physics, had danced around but failed to fill, revealed that a proper understanding of the theory might require a vast network of parallel universes. Everett’s was one of the earliest mathematically motivated insights suggesting that we might be part of a multiverse. (Hidden 218)

Later in The Hidden Reality, Greene further develops this explanation:

In Everett’s approach, everything that is possible, quantum-mechanically speaking (that is, all those outcomes to which quantum mechanics assigns a nonzero probability), is realized in its own separate world. These are the “many worlds” of the Many Worlds approach to quantum mechanics. (ibid. 242)

Everett’s novelty was not simply his employment of the concept of parallel universes to sort probabilities into separate outcomes, but rather his insistence that each outcome not only had the potential to exist but did exist, permanently, in its own version of reality.

While highly controversial, Everett’s theory has fluidly (and sometimes anachronistically) connected quantum theorists with writers of fiction, with Borges and Calvino among them. Allen Thiher, a comparatist studying the intersection of science and fiction, has, in fact, commented on this very connection.29

Theoretical cosmologists have perhaps not looked askance upon Borges in their verbal descriptions of their models. One can hardly avoid thinking of the Borgesian resonances found in the string theorists’ concept of the “multiverse,” in

29Others have commented on this connection as well: Michio Kaku, for example, has stated that “Each universe is linked to every other through a network of forks in the road. Or, as the Argentinian writer Jorge Luis Borges wrote in The Garden of Forking Paths, ‘time forks perpetually toward innumerable futures.’” (Hyperspace 262); Likewise, John D. Barrow has demonstrated his agreement with this assessment, stating that “Borges returned to the dilemma in The Garden of Forking Paths… This is a scenario reminiscent of the ‘many worlds’ interpretation of quantum mechanics, in which all possible histories actually occur.” (Barrow 168); And Alberto Rojo, in Borges científico, has drawn a direct textual connection between Everett and Borges: “Los dos autores presentan la idea central de maneras llamativamente parecidas. En la sección 5 (página 321) del artículo original, Everett dice (la traducción es mía): ‘La ‘trayectoria’ de las configuraciones de la memoria de un observador que realiza una serie de mediciones no es una secuencia lineal de configuraciones de la memoria sino un árbol ramificándose [a branching tree], con todos los resultados posibles que existen simultáneamente.’ Y en ‘El Jardín…’, Borges dice: ‘En todas las ficciones, cada vez que un hombre se enfrenta con diversas alternativas, opta por una y elimina las otras; en el del casi inextricable Ts’ui Pên, opta – simultáneamente – por todas. Crea, así, diversos porvenires, diversos tiempos, que también proliferan y se bifurcan.’” (Borges científico 56-57)
which “the supposition that our entire universe is but one instance of an infinity of continually created universes…” – to cite almost at random a recent description from the journal *Nature*. Mathematical cosmologists can experimentally imagine an infinity of infinite universes. Drawing upon quantum mechanics they have hit upon one of Borges’ working axioms, to wit, that books themselves contain infinite numbers of universes of post-Einsteinian spacetime. A string theorist can thus feel at home in “The Garden of Forking Paths,” in which the narrator of the book within the book, Ts’ui Pên, “different from Newton and Schoepenhauer…did not believe in a uniform, absolute time. He believed in an infinite series of times, in a vertiginous and expanding network of parallel, convergent, and divergent times.” (Thiher 238-239)

While densely suggestive, Borges’ tale is characteristically short and understated; it details a series of events surrounding an English professor named Yu Tsun – a self-described “connoisseur of mazes,” a German sympathizer, and the sole possessor of information regarding the location of a British artillery park – during World War I. The tale itself is a section allegedly taken from Tsun’s own notebooks, in which he describes his flight from a Captain Richard Madden, the allied officer charged with hunting him. The denouement of the plot occurs in a town called Fenton, at the home of a renowned Sinologist named Dr. Stephen Albert.

When Tsun arrives at Albert’s house, the history of Tsun’s great-grandfather (“Ts’ui Pen”) is recounted – he was a nobleman who had attempted to write a massive novel and “construct a labyrinth in which all men would lose their way.” (CF 122) He was murdered, which led to his works remaining unfinished, but Tsun describes his vision of such a maze in terms that can be linked to Hugh Everett’s theory.

I pictured it as infinite – a labyrinth not of octagonal pavilions and paths that turn back upon themselves, but of rivers and provinces and kingdoms…. I imagined a labyrinth of labyrinths, a maze of mazes, a twisting, turning, ever-widening labyrinth that contained both past and future and somehow implied the stars. (ibid. 122)

This evocation of a maze that is overlaid onto reality itself is developed further in the remaining pages of Borges’ tale. Soon after his arrival, Albert invites Tsun to examine what he refers to as
“the garden of forking paths,” a marvel that he attributes to Tsun’s own great-grandfather. Still in flight from Madden, Tsun hesitantly agrees, and is shown a tall, lacquered writing cabinet – an object that suggests the generation of “a labyrinth of symbols… an invisible labyrinth of time.” (ibid. 124) This revelation leads Albert and Tsun to an understanding – the massive novel and the labyrinth that Ts’ui Pen had aimed to create were, in fact, one and the same. The epigraph on the novel left by Pen reads thus: “I leave to several futures (not to all) my garden of forking paths.” (ibid. 125) Further commentary by Albert makes apparent the direct connection with the Many-Worlds Interpretation.

Almost instantly, I saw it – the garden of forking paths was the chaotic novel; the phrase ‘several futures (not all)’ suggested to me the image of a forking in time, rather than in space. A full rereading of the book confirmed my theory. In all fictions, each time a man meets diverse alternatives, he chooses one and eliminates the others; in the work of the virtually impossible-to-disentangle Ts’ui Pen, the character chooses – simultaneously – all of them. He creates, thereby, ‘several futures,’ several times, which themselves proliferate and fork… In Ts’ui Pen’s novel, all the outcomes in fact occur; each is the starting point for further bifurcations. (ibid. 125)

Just as in Hugh Everett’s theory, Pen’s supposition forks every decision, every event and every arrangement of subatomic particles into its own distinct and separate reality – all variations exist, and none of them do not exist. Albert goes on, edging ever closer to what has been echoed by modern physics;

Unlike Newton and Schopenhauer, your ancestor did not believe in a uniform and absolute time; he believed in an infinite series of times, a growing, dizzying web of divergent, convergent and parallel times. That fabric of times that approach one another, fork, are snipped off, or are simply unknown for centuries, contains all possibilities. In most of those times, we do not exist; in some, you exist but I do not; in others, I do and you do not; in others still, we both do. In this one, which the favoring hand of chance has dealt me, you have come to my home; in another, when you come through my garden you find me dead; in another, I say these same words, but I am an error, a ghost… Time forks, perpetually, into countless futures. In one of them, I am your enemy. (ibid. 127)
At this, the story abruptly ends; Yu Tsun, desperate to communicate to Germany the name of the town that houses the British artillery park (a town called “Albert”), murders Stephen Albert and allows himself to be arrested by Richard Madden. While the resolution of this tale does not necessarily echo Everett’s theory, the potential that, in another iteration of reality, Tsun may not murder Albert – or might even be murdered by Albert – is well-established. In Borges’ story, time (and, therefore, reality) forks and bifurcates just as it would in the Many-Worlds Interpretation of quantum physics. The marvel of this, of course, is that Borges’ story was published in 1941 – a full sixteen years prior to Everett’s first presentation of his theory. The fidelity with which Borges’ ideas are reproduced in Everett’s hypothesis is nothing short of astounding, and perhaps represents another moment where fiction’s unfettered creativity was able to produce a theoretical conjecture earlier than science could.

“The Garden of Forking Paths” can be easily linked to Calvino’s work by relating it to “T zero,” a lengthy story that analyzes a confrontation between a hunter and a lion in bifurcating, mathematical terms, essentially exploring the same collapse of probability waves that was discussed earlier in this study. Kirsten Pilz notes that

The story explores the separate time frames, or fragments \((t_0, t_1, t_2, t_3, t_n \ldots)\) as absolutes in the space-time continuum of the universe, making possible the existence of parallel universes, or better, a layering of space and time. In this dazzling story about infinite probabilities and hypothesis, Calvino’s point of view is that of the scientist who contemplates and describes in the precise, rarefied and detached language of his or her field the highly-charged and traumatic moment in which the protagonist contemplates his own death. (Mapping 43)

While absolutely functional as a means of mitigating emotional response through jargonized language, the structure of this tale also serves as a recapitulation of Hugh Everett III’s Many-Worlds interpretation and as an analog to Borges’ bifurcating labyrinth of time.
While the story itself is elementary – a hunter pulls a bowstring and lets fly an arrow toward a lion, unsure of what will occur next – the concepts utilized by the narrator in enumerating the variety of possible outcomes to the situation are advanced. He tells us that “so many and so complex are the factors that condition the parabolic movement both of arrows and of felines that I am unable for the moment to judge which of the eventualities is the more probable.” (T zero 96) Calvino’s narrator presents what is now known as the Cyclic Universe concept, wherein the universe is understood to be cycling endlessly between two extreme points in repeated collapse and expansion. Within this discussion, a statement is made that could almost be mistaken as a quotation from “The Garden of Forking Paths”:

…from the space-time point where I now am there extends bundle of possibilities which, the more they proceed in time, the more they diverge, conelike, toward futures which are completely different from one another, and each time I find myself here with the arrow and the lion in the air will correspond to a different point X of intersection in their trajectories, each time the lion will be wounded in a different way, he will have a different agony or will find to a different extent new strength to react, or he won’t be wounded at all and will fling himself upon me each time in a different way leaving me possibilities of self-defense or not leaving them, and my victories and my defeats in the struggle with the lion prove to be potentially infinite… (ibid. 103)

These potentialities, all existing in “conelike,” parallel futures, have equal validity and are equally plausible – they are in perfect symmetry, then, with what we have seen in Borges and Everett. Whether Calvino’s understanding of this idea came from one, the other or neither is unfortunately impossible to deduce, but the conceptual parity is nevertheless undeniable.

Other works by Calvino also echo the Many-Worlds Interpretation, or at the very least invoke the possibility of bifurcating, parallel futures; the well-known, shattered narrative of If on a Winter’s Night a Traveler… presents, again according to Kirsten Pilz, a “web of intersecting realities or universes.”
Yet all fragments link up into a continuous, irreversible trajectory in the form of the continuous sentence into which the separate titles can be linked, which in turn constitutes a new beginning. And while the novel is headed towards one future – the marriage of the male Reader and Ludmilla – this is rendered unpredictable with every bifurcation, or better interruption, which in turn indicates a multitude of possible futures. (Pilz 153-4)

_The Castle of Crossed Destinies_, too, offers another example of this narrative device in the form of “The Waverer’s Tale.” One of the unnamed characters in the story, mute (as are all of the characters) and reduced to communicating through the combinatorial arrangement of tarot cards, shows himself to be paralyzed by a choice between two brides. He scales a tree to attempt to see where the two diverging roads lead, but is blinded by the sun; he travels to a large city “where all parts are joined, all choices balanced” (Calvino 58) in order to seek guidance, but is instead presented with even more choices; he travels to the sea and is broken down into his prime elements, but even this does not resolve his dilemma. At the tale’s conclusion, in an image that would not be out of place in Borges’ works, the poor man encounters his double:

> But is this really he or is it rather a double whom he saw coming through the forest, the moment he was restored to himself? “Who are you?” “I am the man who was to marry the girl you did not choose, who was to take the other road at the crossing, quench his thirst at the other well. By not choosing, you have prevented my choice.” “Where are you going?” “To an inn different from the one you will come upon.” “Where shall I see you again?” “Hanging from a gallows different from the one where you will have hanged yourself. Farewell.” (ibid. 63)

The Waverer – as this unnamed man is known – had therefore, in attempting to halt the process of bifurcation through his refusal of choice, prevented all other possible futures from coming into existence. The only way to not have to choose, it would seem, is through the final choice of death.

Other traces of the concept of parallel, forking futures can also be found along the windswept route followed by Marco Polo in Calvino’s _Invisible Cities_. In the midst of a dialogue
with his liege, the great Kublai Khan, we are told of Polo’s perspective when he encounters a new land:

Marco enters a city; he sees someone in a square living a life or an instant that could be his; he could now be in that man’s place, if he had stopped in time, long ago; or if, long ago, at a crossroads, instead of taking one road he had taken the opposite one, and after long wandering he had come to be in the place of that man in that square. By now, from that real or hypothetical past of his, he is excluded; he cannot stop; he must go on to another city, where another of his pasts awaits him, or something perhaps that had been a possible future of his and is now someone else’s present. Futures not achieved are only branches of the past: dead branches. (Calvino 29)

What Polo comes across in his travels are not spontaneously generated futures, but branches that have grown independently from his past choices and converged with his own selected present. While there are many such examples to be found in the fictions of Borges and Calvino, enough has been said about the connections to Hugh Everett III and the theories of parallel universes – it would best serve our study to move on to a final section on the nature of time itself, specifically as it relates to the concept of the multiverse.

**Time and Timelessness**

Borges never shied from explicitly probing the characteristics of time in his fictions and essays; “Time and J.W. Dunne,” as an example, is a plainly-worded rebuttal to Dunne’s erroneous conception of time as a fourth dimension of space. Borges explains that Dunne is an illustrious victim of that bad intellectual habit – denounced by Bergson – of conceiving of time as a fourth dimension of space. He postulates that the future toward which we must move already exists, but this postulate merely converts it into space and requires a second time (already conceived in spatial form, in the form of a line or river) and then a third and a millionth. Not one of Dunne’s four books fails to propose the infinite dimensions of time, but those dimensions are spatial. (CNF 219)
Aside from suggesting the by-now familiar Incompleteness Theorem of Kurt Gödel, here Borges is also making an astute statement that reflects his knowledge of current scientific thought: time is not a spatial dimension, at least not in the same way that the three familiar spatial dimensions are manifested. Time exists outside of spatial dimensions, and Floyd Merrell can lend support as to why this is:

Every time-traveling field of presentation, i.e., an observer, is contained within a field one dimension larger, the larger field including events that are simultaneously “past,” “future,” and “present” to the smaller field. For example, our Time, \( T_1 \), is for us linear and trapped within three-dimensional space. To a four-dimensional observer, on the other hand, our time would be tantamount to another dimension of space at right angles to each of the three dimensions of our space, and this observer would see our past, present, and future in simultaneity.

(Merrell 77)

If Dunne has conceived of time as a river or a line, as Borges has suggested, then in order for it to be experienced by 3-dimensional beings it must exist separately from the spatial dimensions, and must not itself be another spatial dimension – if it were, we would experience the full simultaneity of all time without perceiving it as a flow or line. The same theme of the divisibility of time has also been seen in Calvino’s “T zero,” incidentally: the protagonist, unable to attain a 4-dimensional view of the events occurring, is trapped in his 3-dimensional reality and forced to wait until each second passes, slowly unveiling the true succession of events. Time, here, is necessarily nestled within the three spatial dimensions, and does not itself constitute another dimension of space.

Likewise, if we consider Borges’ “The Circular Ruins” we will find a conception of time that appears as both infinite and cyclical to the 4-dimensional viewer (in this case, the “god of Fire”). To all others, however – including the main character and the son he will bring into being through a mental exercise – time is linear, and its horizon is clipped by the human limitation of three spatial dimensions. The plot of this tale is provocative: a sorcerer arrives at a remote temple
in a jungle after an arduous and exhausting journey; the sorcerer rests, using only his intelligence to bring into being a son as he sleeps; with the help of the god of Fire, his son is made flesh, and is sent further down the river to find and ignite yet another temple of the Fire god. The story concludes with the sorcerer’s humiliating realization that, in fact, he was himself the dream of yet another previous sorcerer, and that the line of sorcerers and sons stretches out in both directions to infinity.

Floyd Merrell has exerted no small effort in deconstructing the physical implications of this story, noting the following:

The conditions of the son’s environment are reciprocally identical to those of the magician. Only the infinitely repetitive trees of the jungle separate one temple from another. Hence, the spatial trajectories of father and son compose two symmetrical oppositions, up(stream)/down(south) and down(stream)/up(north), which structurally produce a “cancellation effect.” As a result, the action of the story terminates simultaneously everywhere and nowhere: at the center of the charred ruins of a circular temple where the magician created his dream image… In contrast to these spatial indices, at the outset it appears that time is linear, and it accumulates with increasing torpidity. The magician required fourteen days to perfect the heart of his subject, one year to create the skeleton, a little less than two additional years to complete his project, and two more long years to prepare his son for “birth.” The son’s development, then, is first decelerated and finally halted altogether when the magician interpolates him into the world. However, this effort to annihilate the past is ultimately futile. Temporal recurrence is foretold by the magician’s impression that “all this had happened before.” If the obliteration of “simple location” of space coupled with vague images of spatial circularity implies a denial of linear movement, concomitantly, the attempt to annihilate the past and establish an eternal “now” stems from an implicit attempt to deny temporal irreversibility. (Merrell 34-35)

This attempt, of course, is doomed to fail, as is evidenced by the sorcerer’s late attempt at self-immolation as the temple is engulfed in flame. The full scope of his action’s futility sinks in when the roaring flames miraculously have no discernable effect on his body. Merrell expresses the interpretation that time may have “begun” when the sorcerer began creating his son, and that
time “ended” when the son was finally made flesh. Baudrillard figures well here, too, having stated that “by crossing into a space whose curvature is no longer that of the real, nor that of truth, the era of simulation is inaugurated by a liquidation of all referentials…” (Baudrillard 2)

This “liquidation” is symmetrical with the annihilation of the temple by flame.

Upon deeper reflection, however, we will find that Merrell’s position is incomplete – if the process of continual regeneration and annihilation is conceived of as analogous to that of a circular universe (e.g. a universe that repeatedly contracts and expands from a zero-point), then time is not only stopped but also reversed and undone with each arrival at zero – this is known in physics as the Big Crunch. Rather than a linear succession of Big Bangs and Crunches that always move linearly forward in time, the circular universe is more akin to a palimpsest. With each new cycle, the previous data is overwritten; in effect, it never existed. If this is the case in “The Circular Ruins,” then Borges’ sorcerer is the embodiment of a denial of the linearity of time, since all of his work will have been undone at the peak of the universe’s reversal. Michio Kaku uses Kurt Gödel’s ideas to present an image that is similar to this conclusion:

If one followed the path of a particle in a Gödel universe, eventually it would come back and meet itself in the past… Gödel showed that the river of time could be smoothly bent backward into a circle. Rivers, after all, have eddy currents and whirlpools. In the main, a river may flow forward, but at the edges there are always side pools where water flows in a circular motion. ([Hyperspace](#) 243)

The aquatic metaphor here is especially apt, as the continuum joining all sorcerers and their sons is the story’s endless river, bridging all temples together over linear space and circular time.

Borges’ own words suggest such circularity, as well – “From time to time, he was disturbed by a sense that all this had happened before…” (CF 99); and, later: “…for that which had occurred hundreds of years ago was being repeated now.” (ibid. 100)
A final example of the Borgesian treatment of time can be found in one of his lesser-known fictions, entitled “The Secret Miracle.” Jaromir Hladik, a Jewish writer from Prague, is captured by the Third Reich and sentenced to death. His oeuvre is a subtle hint on Borges’ part to the primacy of time in this story:

He judged *A Vindication of Eternity* to be less unsatisfactory, perhaps. The first volume documents the diverse eternities that mankind has invented, from Parmenides’ static Being to Hinton’s modifiable past; the second denies (with Francis Bradley) that all the events of the universe constitute a temporal series. It argues that the number of humankind’s possible experiences is *not* infinite, and that a single “repetition” is sufficient to prove that time is a fallacy…. Unfortunately, no less fallacious are the arguments that prove that fallacy. (ibid. 159)

Hladik waits for his execution over several days, fretting over the nature of time; his mind eventually settles on the matter of his lamentably unfinished play, *The Enemies*, which is itself a reflection of the author’s meditations on time; the narrator tells us that “this play observed the unities of time, place and action.” (ibid. 159) Through each of these hints, Borges is preparing the reader for the real action of this tale, which lies in the events of Hladik’s execution; as the character stands against the wall of the execution yard and the Nazi sergeant raises his arm to signal a lethal salvo of gunfire, the narrator announces, simply, that “the physical universe stopped.” (ibid. 161)

The weapons converged upon Hladik, but the men who were to kill him were immobile… Hladik attempted a scream, a syllable, the twisting of a hand. He realized that he was paralyzed. He could hear not the slightest murmur of the halted world. *I am in hell*, he thought, *I am dead*. Then *I am mad*, he thought. And then, *time has halted*… He had asked God for an entire year in which to finish his work; God in His omnipotence had granted him a year. God had performed for him a secret miracle: the German bullet would kill him, at the determined hour, but in Hladik’s mind a year would pass between the order to fire and the discharge of the rifles. (ibid. 161-2)

While Borges suggests a patently metaphysical reason for this halt in the flow of physical time, our study will attempt a more scientific conjecture: the only known location in the universe at
which time can come to a stop is the singularity at the center of a black hole. The mass of such singularities is so immense that space becomes infinitely curved at their centers, thereby halting time. At the risk of seeming cheeky, we might consider the elevation of the “gravity” of Hladik’s situation – embodied in his impending death – as conceptually analogous to the massive gravity of a singularity. At both points, due to high gravity, time comes to a stop, either literally or figuratively. We would not be alone in making this connection – another scholar, Héctor Vucetich, shares our view: “Esta negación del tiempo de Borges, la afirmación de que presentes simultáneos representan historias temporales incompatibles, tiene contrapartes en varias de las ramas de la física moderna.” (Vucetich 66)

One could, of course, posit that what occurred to Hladik in this particular story is invalidated by the fact that it was purely mental, but Brian Greene creates space for flexibility in our interpretation.

Each moment – each event or happening – exists, just as each point in space exists. Moments don’t momentarily come to life when illuminated by the “spotlight” of an observer’s present; that image aligns well with our intuition but fails to stand up to logical analysis. Instead, once illuminated, always illuminated. Moments don’t change. Moments are. Being illuminated is simply one of the many unchanging features that constitute a moment… If you time-traveled back to December 31, 1965, then you were there, you were always there, you will always be there, you were never not there. December 31, 1965, did not happen twice, with your missing the debut but attending the encore. (Fabric 452-3)

Based on this understanding, the possibility remains for the (albeit fictional) “reality” of Hladik’s experience and our subsequent comparison of it to high-gravity singularities. Despite any dilation or compression of space-time, the relative “reality” of experiences is not invalidated. We can think of this in terms of the multiverse, as well; the moments that occur in this universe or time do not replace the moments that occur in another universe or time – they all exist, forever.
While Calvino does not tend to address the issue of recursive or paused time in the same way as Borges (though some tales from *Cosmicomics* that we have already discussed come close), two examples from *Invisible Cities* will draw our analysis toward an equitable conclusion.

In his description of the city of “Laudomia,” Calvino presents the by-now familiar conceptualization of reality as an overlaid simultaneity of past, present and future. With the parallel cities of living Laudomia, dead Laudomia and unborn (read: “future”) Laudomia all adjacent to one another, all times coexist in the same patch of space.

The living of Laudomia frequent the house of the unborn to interrogate them; footsteps echo beneath the hollow domes; the questions are asked in silence; and it is always about themselves that the living ask, not about those who are to come. One man is concerned with leaving behind him an illustrious reputation, another wants his shame to be forgotten; all would like to follow the thread of their own actions’ consequences; but the more they sharpen their eyes, the less they can discern a continuous line. (Calvino 142)

The invocation of this “continuous line” is not dissimilar to what was noted in Borges’ “The Circular Ruins,” just as the four-dimensional overlay of past-present-future is not far removed from that of “Time and J.W. Dunne”; Calvino is toying more abstractly with the same concepts as Borges, imbuing his own experimentation with his characteristic cynicism and melancholy.

The other example from *Invisible Cities*, “Berenice,” echoes a similar overlay of past, present and future, with an analogous 3-dimensional perspective on the part of its inhabitants. Between the “just” and “unjust” versions of Berenice that coexist, there is a third city – the future Berenice – “germinating.”

From my words you will have reached the conclusion that the real Berenice is a temporal succession of different cities, alternately just and unjust. But what I wanted to warn you about is something else: all the future Berenices are already present in this instant, wrapped on within the other, confined, crammed, inextricable. (ibid. 163)
Again, the opposition of the linearity of time in three dimensions is juxtaposed with their coincidence in four dimensions – while this is obviously a concept that was dear to Calvino, it also functions as yet another unifying theme between he and Borges.

We will conclude this chapter with a brief statement on the feasibility of manipulating time, both in ways that have been illustrated by these authors and through the perennial trope of traveling through time. While categorically impossible according to both our current theories and present technology, this door is not necessarily bolted shut for future generations of humans. Michio Kaku has effectively summarized the current state of affairs:

For any physicist who has seriously analyzed the mathematics of time travel within Einstein’s general theory of relativity, the final conclusion is, surprisingly enough, far from clear… Although time does slow down when you increase your velocity, you cannot go faster than the speed of light (and hence make time go backward) because special relativity states that your mass would become infinite in the process. Thus the faster-than-light travel method preferred by most science-fiction writers contradicts the special theory of relativity. (Hyperspace 233)

While humanity is far from overcoming this limitation, contemporary developments in physics (including string theory) are laying the foundation for future advances in the manipulation of space-time. Literature, for its own part, may eventually serve as it has before: as the unbridled, creative catalyst behind such eventual advances in physical science.
Self-similarity

The modern age of science has brought a new awareness of the exponential complexity of the universe around us. The study of self-similarity, which was codified and developed by Mitchell Feigenbaum and the late Benoit Mandelbrot and has come to be known colloquially as “Chaos Theory,” revolutionized the art of systemic projection and modeling. Kerstin Pilz, in an introduction to a study of self-similarity in Calvino, has presented a clear image of the current landscape in this field of study:

The new sciences… focus on the way the macroscopic world really behaves: it is a complex, unruly, often nonlinear and indeterminate one, where microscopic causes can quickly produce macroscopic effects. However, these theories, unlike the implications of the somewhat misleading tem “chaos science,” are not concerned to show that chaotic systems exist, but that they display a deep relation with order. (Pilz XV)

Despite its misleading moniker, Chaos Theory is, as Pilz emphasizes, much more concerned with the underlying order that props up the supposed unruliness of the universe. A major researcher in this discipline and the author of a field-defining history of Chaos Theory, James Gleick presents the following explanation of its development:

Where chaos begins, classical science stops. For as long as the world has had physicists inquiring into the laws of nature, it has suffered a special ignorance about disorder in the atmosphere, in the turbulent sea, in the fluctuations of wildlife populations, in the oscillations of the heart and the brain. The irregular side of nature, the discontinuous and erratic side – these have been puzzles to science, or worse, monstrosities. But in the 1970s a few scientists in the United States and Europe began to find a way through disorder. (Gleick 3)

This “erratic” or apparently unpredictable aspect of nature is precisely what is confronted in complexity science – Gleick defines the microscopic scale of Chaos Theory’s project:
In science as in life, it is well known that a chain of events can have a point of crisis that could magnify small changes. But chaos meant that such points were everywhere. They were pervasive. In systems like the weather, sensitive dependence on initial conditions was an inescapable consequence of the way small scales intertwined with large. (Gleick 23)

Such a confluence of myriad tiny anomalies eventually leads, in aggregate, to situations which earlier versions of the scientific method were powerless to resolve. This quandary immediately brings to mind the Sisyphean task of Calvino’s Mr. Palomar, who comes across these “points of crisis” with every attempt to condense nonlinear phenomena (ocean waves, flocks of birds, varieties of cheeses) into simplified, linear axioms. Incidentally, this same struggle is echoed in the historic toils of Blaise Pascal, Georg Cantor and the quantum physicists of the last century, all of whom have been discussed previously in this study.

If so-called Chaos Theory’s defining principle is the recognition and subsequent modeling of natural self-similarity, then the literary equivalent of such a concept must be identified as *mise en abyme*, which sets a particular image inside of a smaller version of itself, with the suggestion that such scaling may continue on into infinity. Its function is that of introducing self-reflexivity and multiplicity in the image, but also of affecting an unsettling bewilderment and confusion in the reader. Across Borges’ considerable body of fiction, a number of tales employ self-similarity as a descriptive technique, several of which we have already analyzed: “The Cult of the Phoenix”; “The Circular Ruins”; “The Approach to Al-Mu’tasim”; “The House of Asterion”; “The God’s Script”; “The Waiting.” As for Calvino’s employment of recursive self-scaling, we can look to Albert Sbragia’s commentary on the topic:

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30Interestingly, Benoit Mandelbrot seems to have shared Calvino’s interdisciplinary visage of the ideal intellectual. Gleick quotes him as having said, “Science would be ruined if (like sports) it were to put competition above everything else, and if it were to clarify the rules of competition by withdrawing entirely into narrowly defined specialties. The rare scholars who are nomads-by-choice are essential to the intellectual welfare of the settled disciplines.” (Gleick 90)
Synecdoche and *mise en abyme* are Calvino’s unruly tools in his attempt to impart order to his fictional universe… This is not surprising since synecdoche and *mise en abyme* are perhaps the purest examples of language’s tendency to constitute itself according to the principles of contiguity and similarity… Chaotic systems possess order in the form of periodic repetition of symmetries across scale levels. At the same time, initial aperiodic variations or contiguities are reintroduced and magnified at each scale level by the system’s own feedback mechanisms. It is something similar to find *mise en abyme* and synecdoche operating in the same system. The contiguous irregularities impart change and evolution to the bedrock of symmetrical order that holds the universe together. The result is creation. (Sbragia 301)

Sbragia follows this perspicacious statement with a more specific citation of the contiguity found in two of Calvino’s works, *Invisible Cities* and *The Nonexistent Knight*.

> In *Invisible Cities*, the all-powerful despot Kublai Khan yearns for Marco Polo to provide him with the “tracery of a pattern” that will give meaning to the formless ruin of his empire. Agilulf, the nonexistent knight, arranges pine cones in precise geometrical forms to overcome the malaise that assails him at dawn, the hour in which the world seems to melt into the vague and ambiguous. Almost all of Calvino’s characters suffer from an acute hypersensitivity to the disorder of the world. (Sbragia 292)

Polo’s journey ended before it began, of course, with the realization that in order to accurately map such a formless and shifting expanse one would need a map the same size of the earth itself, overlaid upon all things, all cities and all people. As a foil to Agilulf, the obsessive-compulsive, invisible horseman, Calvino gives us the comical character of Gurdulú – a man who is “without a name and with every possible name,” (Calvino 53) a “squire to the air” (ibid. 137) – who exclaims that the world around us, in its befuddling complexity, is “all soup.”³¹

> *The Nonexistent Knight* offers more than simple recursive gags and quips, however – Sbragia notes that Agilulf

exists not by means of a metonymical presence within the world, but through sheer force of idea and will. The knight’s shield, with its herald of a cloaked coat of arms within a series of other cloaked coats of arms, attests to its owner’s metaphysical nature through recourse to what André Gide saw as the heraldic etymology of *mise en abyme*. (Sbragia 298)

³¹We might also note that soup, in its liquidity and heterogeneity, is a highly entropic food! - MR
The symbol *par excellence* for the unorthodox character of Agilulf is precisely that emblem of self-scaling/self-similarity that we have introduced, which ties together the overlapping concepts of both science and fiction. Other signs connecting these characters to the concepts of complexity science can be found within the context of *The Nonexistent Knight* – Kerstin Pilz has noted that

Gurdulù, devoid of subjectivity, is incapable of separating himself from nature by conceiving an independent, rational relationship with the world. He identifies with the flux of organic matter and merges with the people or objects he comes in contact with, thereby assuming multiple and fluid identities. Agilulf, on the other hand, deprived of a physical self, is a symbol of pure rationality and of the abstraction that has replaced an organic, holistic conception of the world. (Pilz 10)

Neither of these personages is complete – they each represent half of what would be a unifying conception of the universe; Gurdulù represents infinity as pure chaos, with no recurring patterns to be found anywhere in its totality, while Agilulf embodies the idea of infinity as pure order, presumably achieved through the self-scaling and endlessly replicating processes of complexity science.

In *Mr. Palomar*, Calvino has again embedded self-scaling and spiraling images – in fact, the structure of the book is itself a recursive pattern, with each chapter composed of three progressively more abstract and complex sections (nine chapters equaling 27 individual sections, with each component divisible by three). Jerry Varsava has identified a geometrical thread running through a number of these sections:

[Palomar] ventures to three non-Western locales, extrapolating an important lesson from the events at each one. Visiting the famous garden of rocks and sand of the Ryoanji of Kyoto, Palomar finds himself incapable of following the Zen Buddhist imperative of shedding one’s personality in order to intuit “Absolute Self.” For Palomar, personality is an inextricable part of being. In gazing at the configuration of rocks and sand, he identifies two “nonhomogenous harmonies”: the harmony of capricious, unpatterned, natural forces, and the harmony of
regular human structures that “aspire to the rationality of a geometrical or musical composition, never definitive.” (Varsava 195)

Sbragia has noted the same opposition in Palomar’s understanding of the universe as either “regular and ordered cosmos” or “chaotic proliferation.” (Sbragia 284) The error of this position, and presumably Calvino’s main point throughout the work, is that chaos and order are not separated but actually intrinsic to one another. That natural geometric patterns and human structures both aspire to the same type of coherence is simply evidence of man’s crucial position as nature’s mouthpiece; as Carl Sagan famously stated in the introductory episode of Cosmos: A Personal Voyage (1980), “we are a way for the cosmos to know itself.” Mr. Palomar is practically a satire of humans’ difficulty in accepting disorder and irregularity in their lives, as well as a reflection of the weakness of traditional science when confronted with the immense, spiraling complexity of nature.

This anguished struggle to categorize and simplify the universe is found throughout Palomar’s enterprises: the first section, “Reading a Wave,” introduces the reader to the central agon of the book, along with the main character’s anxious personality.

Mr. Palomar is standing on the shore, looking at a wave. Not that he is lost in contemplation of the waves. He is not lost, because he is quite aware of what he is doing: he wants to look at a wave and he is looking at it… it is not “the waves” that he means to look at, but just one individual wave: in his desire to avoid vague sensations, he establishes for his every action a limited and precise object. (Calvino 3)

This is simply not to be, however – as Palomar moves from unsuccesssfully delineating individual waves (which cannot be done without inadvertently including a portion of the successive or preceding wave) into increasingly minute distinctions between discrete elements, he begins to feel a “slight dizziness.” (ibid. 7) Finally, he is overwhelmed and exasperated; “Mr. Palomar goes off along the beach, tense and nervous as when he came, and even more unsure about
everything.” (ibid. 8) Most of Palomar’s endeavors end in this way, with a sad resignation toward the ultimate impossibility of truly “knowing” any aspect of reality. Pilz has noted Calvino’s impetus for establishing this pattern:

The difficulty of how to reconcile the multiple with the singular is of key importance in Calvino’s writing, creating a tension that motivates his incessant search for and reflection on method. He does so with an eye to the issues of contemporary science, namely chaos theory and complexity science which are similarly concerned with the problem of how to describe complex, irregular and turbulent forms in nature. (Pilz 66)

“The Invasion of the Starlings” also demonstrates the same tension that Pilz has described; Palomar experiences a temporary moment of unity with a massive flock of birds, only to have this bond be immediately dissolved by his need for order.

If he lingers for a few moments to observe the arrangement of the birds, one in relation to another, Mr. Palomar feels caught in a weft whose continuity extends, uniform and without rents, as if he, too, were part of this moving body composed of hundreds and hundreds of bodies, detached, but together forming a single object, like a cloud or a column of smoke or a jet of water – something, in other words, that even in the fluidity of its substance achieves a formal solidity of its own. But he has only to start following a single bird with his gaze and the disassociation of the elements returns. (Calvino 63)

Palomar cannot be satisfied with collective nouns like “flock” or “tides” – his stodgy, formalist perspective requires an intimate knowledge of all individual elements, which is obviously impossible and leads to unceasing disappointment throughout the book. This cycle of failed scientific analysis and augmented anxiety only finds its end in “Learning to be Dead,” the final section of the book in which Palomar, riddled with acute anxiety, reaches his limit. “He decides that he will set himself to describing every instant of his life, and until he has described them all he will no longer think of being dead. At that moment he dies.” (ibid. 126)

Despite offering such a pat, cynical solution to the problem of complexity in this particular case, Calvino has stated elsewhere that he considers himself “a ‘partisan’ of the
crystal, that is to say, a seeker of order within disorder.” (Six Memos 71) This same image of the crystal – itself, perhaps the best symbol in nature of the process of self-scaling replication – is presented in an eponymous chapter of T zero (“Crystals”). The story narrates a dialogue between the characters Qfwfq and Vug, in which they debate the existence and characteristics of an underlying universal order.

I play the game, in other words, the game of pretending there’s an order in the dust, a regularity in the system, or an interpenetration of different systems, incongruous but still measurable, so that every graininess of disorder coincides with the faceting of an order which promptly crumbles… Of course, if he chooses, a person can also take it into his head to find an order in the stars, the galaxies, an order in the lighted windows of the empty skyscrapers where between nine and midnight the cleaning women wax the floors of the offices. Rationalize, that’s the big task: rationalize if you don’t want everything to come apart. (Calvino 30-33)

Qfwfq’s counterpart Vug, however, has an appreciation for the anomalous, the violation of order that creates strangeness and, therefore, beauty. After the earth opens, spewing forth a mountain of varied gems and crystals, Vug becomes enamored with them, with the exception of the diamond, whose clarity demonstrates a perfection of symmetry and the absence of anomalous elements.

In an aluminum crystal, where chance scatters some chrome atoms, the transparency is colored a dark red: so the rubies flowered beneath our footsteps. “You see?” Vug said. “Aren’t they beautiful?” We couldn’t walk through a valley of rubies without starting to quarrel again. “Yes,” I said, “because the regularity of the hexagon…” “Uff!” she said. “Would they be rubies without the intrusion of extraneous atoms? Answer me that!”…Vug seemed to take pleasure only in noting how minutely variegated the face of the world appeared… She wants to make me admit that real order carries impurity within itself, destruction. (Calvino 36-37)

Kerstin Pilz succinctly captures the central conflict of this tale:

A representative of the logocentric tradition of Western thought which produced classical science, here Qfwfq is challenged by a new vision of order, a new form of rationality that emphasizes, rather than ignores, disorder…The tension between
the two characters points to Calvino’s own slow reorientation towards postmodern theories of science which emphasise indeterminism and chaos. (Pilz 46-47)

Guy Raffa has also offered a similar analysis:

Whereas Qfwfq takes positions consistent with basic assumptions of Newtonian science (e.g. reversible time, linear equations) and classical ideas of harmony and proportion, Vug’s embrace of asymmetries and unforeseen variations puts her in dialogue with the scientific and cultural paradigm shift that has been intriguingly (if controversially) popularized as ‘chaos theory’ and more accurately described as the study of ‘nonlinear dynamics’ or complex, ‘dissipative’ systems. (Raffa 283)

Chaos Theory has essentially come to prove the consistency of Vug’s position, which is that the truest underlying order of the universe is not bounded within the parameters of traditional Euclidean geometry. On the contrary, reality is “variegated” instead of smooth, with a rough, random unpredictability that is built into its self-replication process.

Benoit Mandelbrot, whom we have identified as one of the founders of complexity science, ushered a powerful new word into the scientific lexicon and defined a new branch of geometry. The “fractal” – a shorthand term for the clunkier “fractional dimension” – became a powerful new tool for mathematicians to wield in their attempts to codify the order of the natural universe.

Mandelbrot moved beyond dimensions 0, 1, 2, 3… to a seeming impossibility: fractional dimensions. The notion is a conceptual high-wire act. For nonmathematicians it requires a willing suspension of disbelief. Yet it proves extraordinarily powerful. Fractional dimension becomes a way of measuring qualities that otherwise have no clear definition: the degree of roughness or brokenness or irregularity in an object… [Mandelbrot’s] claim was that the degree of irregularity remains constant over different scales. Surprisingly often, the claim turns out to be true. (Gleick 98)

All of those variegated points (coastlines, leaves, snowflakes) that had resisted full mapping by traditional geometric rules could now be defined fractionally, allowing a savvy user to identify smaller and smaller patterns within literally any object in the universe. Gleick goes on:
The mind cannot visualize the whole infinite self-embedding of complexity. But to someone with a geometer’s way of thinking about form, this kind of repetition of structure on finer and finer scales can open a whole world… [Mandelbrot’s] studies of irregular patterns in natural processes and his exploration of infinitely complex shapes had an intellectual intersection: a quality of self-similarity. Above all, fractal meant self-similar. Self-similarity is symmetry across scale. It implies recursion, pattern inside of pattern. (Gleick 100-103)

As has been demonstrated, this description of self-scaling is essentially identical to the literary device of *mise en abyme*. Just as we have previously described elements of Borges’ and Calvino’s writing as “entropic” in their tendency to increase in complexity and disorder, so could we also describe them as “fractal” in their employment of self-similar imagery and recursive patterns. Gleick has noted, in fact, that many disparate fields have begun to appropriate the terms of Chaos Theory: “Aspects of chaos – different aspects, usually – have been taken up by modern management theorists on the one hand, and postmodern literary theorists on the other. Both camps have found use for phrases like “orderly disorder,” especially popular in dissertation titles…” (Gleick 320) While intentionally ironic in his statement, Gleick also helpfully identifies the significance of the fractal through its primary utility across all arenas: “A fractal curve implies an organizing structure that lies hidden among the hideous complication of such shapes.” (Gleick 114) We can only imagine what poor, doomed Palomar might have achieved had he possessed the wherewithal to employ fractal geometry in his analyses of the cosmos!

Although we have focused heavily on Calvino’s works in this chapter – perhaps in compensation for having leaned overmuch on Borges in the previous one – Borges nevertheless shares Calvino’s penchant for deploying *mise en abyme* as a multiplicative, complicating mechanism.32 As “The Library of Babel” has already been discussed in great detail, we will

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32 For as much as Borges was an influence on Calvino, we might even propose that Calvino *learned* this technique from his mentor. - MR
allow a quotation from Floyd Merrell to assist in joining Borges to our discourse on Chaos Theory.

Interestingly enough, the hexagonal structure of each miniscule gallery in Borges’ Library reduplicated indefinitely such that the library appears to become more and more sphere-like as the sides of each hexagon become smaller relative to the whole… creates an image that raged in recent years going by the name of \textit{fractal geometry}… Starting with an equilateral triangle, the first step yields three identical triangles on each side, making a six-pointed star, the second gives twelve more triangles, and the third an additional thirty-six to produce a “snowflake” image. At the theoretical upper limit we would have a continuous “curve” with an infinite number of infinitesimal barbs or excursions. Like Borges’ Library, the “curve” would be monstrous. It would be impossible to visualize. Possessing no tangent, it would change direction radically at each and every point. In a sense, it would be infinitely irregular, or infinitely regular, take your pick… (Merrell 200-201)

According to Merrell – who is no novice when it comes to advanced mathematics – Borges’ infamous library possesses a fractal shape that is both absolutely anomalous and perfectly ordered. As the natural generation of fractals is driven partially by random selection and variation, one cannot know for sure what qualities or orientation each successive branch will possess; for this reason, just as there exists an infinite variety of unique snowflakes, so would Borges’ library possess, at regular intervals, an endless variety of hexagonal galleries, each with their own unique arrangement of perforations, nooks and crannies.

Just as Merrell found fractals in the Library, so have critics Gabriel Schreiber and Roberto Umansky noted the presence of self-similarity in “The Garden of Forking Paths.” They begin by equating the term “bifurcation” with the concept of non-linear self-replication, while at the same time invoking a name from an earlier chapter of our own study:

The term bifurcation was coined by [Henri] Poincaré to designate the emergence of several solutions from a given solution… From a bifurcation point several stable or unstable solution branches emerge. Successive bifurcations lead to an irregular and unpredictable time evolution of deterministic nonlinear systems, which is designated chaos. (Schreiber 61)
While still remaining abstract, Schreiber and Umansky have honed this concept enough for us to tentatively consider the fabled maze of Borges’ Ts’ui Pen a “fractal” or “chaotic labyrinth.”

Borges’ character Dr. Stephen Albert explicitly states that Ts’ui Pen’s labyrinth forks “in time, not in space,” but Schreiber and Umansky make a clear distinction between the two terms: fractals involve space, and chaos involves time. (Schreiber 65) They continue:

Though Borges devotes the garden of forking paths [sic] to bifurcation in time [and] not in space, to chaotic aspects and not to fractal geometric aspects, the latter appear… almost unnoticeably in the story… The objects seen, or let us say conceived, out of the window are clearly Euclidean: roofs and sun. Fractal appearances like clouds are regarded as a hindrance with regard to the purity of the Euclidean object… (ibid. 72)

On the other hand, they also note that

Borges looking out of the window to the fractal geometry of nature is radically different from the previous Euclidean view…Here the picture is composed of fractal objects: “trees, a mountain, water, rivers[,] etc.,” while Euclidean geometry is an interference. Euclidean objects are regarded as a hindrance with regard to the beauty of the fractal object. (ibid. 73)

Schreiber and Umansky conclude by reemphasizing the primacy of fractal shapes in Borges’ oeuvre; “Beautiful ‘fractals’ with their self-similarity and scaling lows are scattered everywhere in Borges’ writings… Scaling features, self-similarities, and fractal topologies are the backbone of Borges’ writing.” (ibid. 74-77) While their essay seems somewhat incomplete, Schreiber and Umansky have nonetheless unearthed a remarkable pattern in “The Garden of Forking Paths,” which draws yet another connecting thread between Calvino, Borges and the most cutting-edge science of their time.

Before moving on to the next section of this study, it would be fitting to conclude our discussion of fractals with a final word about the man who invented them; James Gleick has warmly contextualized the importance of Mandelbrot’s innovation:
The shapes of classical geometry are lines and planes, circles and spheres, triangles and cones. They represent a powerful abstraction of reality, and they inspired a powerful philosophy of Platonic harmony. Euclid made of them a geometry that lasted two millennia, the only geometry still that most people ever learn. Artists found an ideal beauty in them, Ptolemaic astronomers built a theory of the universe out of them. But for understanding complexity, they turn out to be the wrong kind of abstraction. Clouds are not spheres, Mandelbrot is fond of saying. Mountains are not cones. Lightning does not travel in a straight line. The new geometry mirrors a universe that is rough, not rounded, scabrous, not smooth. It is a geometry of the pitted, pocked, and broken up, the twisted, tangled and intertwined... Mandelbrot’s work made a claim about the world, and the claim was that such odd shapes carry meaning. The pits and tangles are more than blemishes distorting the classic shapes of Euclidean geometry. They are often the keys to the essence of a thing. (Gleick 94)

Mandelbrot’s nuanced awareness that nature’s foundation is comprised of innumerable tiny, independent elements – “initial conditions,” as he tended to call them (Gleick 23) – is in direct contact with the structural sensitivity shown by Jorge Luis Borges and Italo Calvino in their works of fiction. An interstitial section of Invisible Cities will illustrate this connection:

“And yet I know,” [the Khan] would say, “that my empire is made of the stuff of crystals, its molecules arranged in a perfect pattern. Amid the surge of the elements, a splendid hard diamond takes shape, an immense, faceted, transparent mountain. Why do your travel impressions stop at disappointing appearances, never catching this implacable process? Why do you linger in inessential melancholies? Why do you hide from the emperor the grandeur of his destiny?” And Marco [Polo] answered: “While, at a sign from you, sire, the unique and final city raises its stainless walls, I am collecting the ashes of the other possible cities that vanish to make room for it, cities that can never be rebuilt or remembered. When you know at last the residue of unhappiness for which no precious stone can compensate, you will be able to calculate the exact number of carats toward which that final diamond must strive. Otherwise, your calculations will be mistaken from the very start.” (Calvino 60)

The Khan and Polo, here, disagree on the method through which to map the empire – while the Khan would simply catalog the macroscopic, apparent symmetry of his realm, Polo instead mimics Mandelbrot’s method. Polo would focus his analysis on the “initial conditions” of the Khan’s empire – those cities that failed, those cities that never came into being, and those cities that have been forgotten – in order to better establish all of the tiny, hidden elements and events
that have led to the current state of the khanate. By employing the techniques of Chaos Theory and fractal geometry in projecting current and future behavior (a process now known colloquially as the “Butterfly Effect”), Polo shows himself as kin of Mandelbrot and Borges, both of whom engaged in the very same exercises, albeit in disparate fields.

**Post-humanity & Cybernetics**

While many of the most famous advances in science have taken place in the areas of astrophysics and mathematics, there have been great leaps made in the biological and physiological sciences as well. Recent years have brought both confirmation and conjecture about the evolution and ultimate fate of the human body, with theorists attempting to plot the continued development of our species. Many have also begun to intervene in the evolutionary process through the fusion of machine and man – one need only consider the mechanical hearts, lungs and limbs that have propelled medicine into a new era. As this process of discovery and experimentation continues, our descendents may eventually see the concept of the human being redefined to include semi-humans, sentient machines and the perpetual darling of science fiction: the “cyborg.”

The concept of the fusion of man and machine is not new – while the last three decades have seen the introductions of Blade Runner, RoboCop, the Terminator and Darth Vader, the first known appearance of a literary cyborg can be found in “The Ablest Man in the World,” an 1879 story by Edward Page Mitchell that recounts the insertion of a computer into a man’s head (an operation that renders him a genius). More recently, viewers of the television series *Star Trek: The Next Generation* were moved and compelled by the character of Data, a cybernetic organism (technically an “android”) that was comprised of a highly-adaptive artificial
intelligence, along with both organic tissue and a biomechatronic infrastructure. While his biological functions mimicked those of any normal human, his electronic mind was not pre-programmed to understand complex emotions. Over time, during the course of his interactions with the humans on his crew, he began to learn to “feel” in the same way that human beings do. He eventually sacrificed his own life for those of his compatriots in a final act of altruism, that most inexplicable and counterintuitive of human emotions. We cannot know if science will ever be able to attain such a level of subtle prowess, but we can be sure that long before Star Trek both Borges and Calvino were aware of and intrigued by concepts that are not dissimilar to that of the man-made, synthetic organism.

In 1944, Jorge Luis Borges published a collection of fictions entitled Artifices that included the tales “Death and the Compass” and “The Secret Miracle,” which we have already analyzed in this study. This collection opened, however, with a rather inert story called “Funes, His Memory” (often alternately translated as “Funes the Memorious”), which introduces the character of Ireneo Funes, a young man who has been crippled by a horse and has subsequently – and unexpectedly – come to possess a flawless, practically electronic memory. From the start, Funes is presented as a cybernetic half-human, particularly in the emotional sense; Borges tells us that

[Funes] had lived, he said, for nineteen years as though in a dream: he looked without seeing, heard without listening, forgot everything, or virtually everything. When he fell, he’d been knocked unconscious; when he came to again, the present was so rich, so clear, that it was almost unbearable, as were his oldest and even his most trivial memories… Now his perception and his memory were perfect. (CF 134-5)

Gabriel Kreiman, a neuroscientist, published a piece on Borges’ character in the scientific journal Nature that confirms the assessment that Funes could be seen as a proto-cyborg.
Because of his prodigious memory, Funes always knows the precise time without having to consult his watch, learns languages after merely checking a dictionary and can enumerate all the people he has ever met. Although these abilities seem admirable, there is a catch. Every leaf of every tree that he has ever seen remains in his mind. It disturbs him that a front view of a face is assigned the same identity as the profile view. He is almost incapable of understanding or creating abstract ideas. (Kreiman 453)

While we cannot confirm Borges’ explicit awareness of the term “cyborg” as a scientific concept, the literary antecedents found in popular and science fiction before and during his lifetime could certainly have drawn the awareness of such a broadly well-read man. In fact, Borges does describe Funes as “a precursor of the race of supermen,” a fact that is reinforced by Stefan Herbrechter and Ivan Callus in their playfully-named Cy-Borges: Memories of the Posthuman in the Work of Jorge Luis Borges.

Funes, in many respects, could be seen as an “embodiment” of the Nietzschean “overman” but also maybe as a posthuman in the sense that the narrator describes the infallibility of his memory – a perfect recording device that one might provocatively name “cyborg memory,” even if it of course lacks a hypermnesic technology. (Herbrechter 22)

They also quite astutely cite another of Borges’ statements, one that we also isolated in our analysis of “Pierre Menard, Author of the Quixote”: “sooner or later all men will do and know all things.” (ibid. 22) Such a statement, coupled with Borges’ previous invocation of the Zarathustran “superman,” provides us with just enough evidence to tentatively regard Funes as a Borgesian cyborg, at least in terms of pure processing power. Like Star Trek’s Data, Funes, “we must not forget, was virtually incapable of general, platonic ideas… He had effortlessly learned English, French, Portuguese, Latin. I suspect, nevertheless, that he was not very good at thinking.” (CF 136-7)
Our assessment of Funes as a man possessing a brain like that of a computer must remain tentative, however; Rodrigo Quian Quiroga, a neuroscientist and bioengineer also writing in the journal *Nature*, raises the point that Funes could simply be functionally brain-damaged.

In the story of Funes, Borges described very precisely the problems of distorted memory capacities well before neuroscience caught up. We now know that memory function is linked to a particular brain area, the hippocampus, which lies at the end of the neural pathway that processes sensory information. (Quian Quiroga 611)

Quian Quiroga goes on, focusing on the operations of the neurons therein:

> It is thus possible that that these neurons link perception and memory by creating the abstract encoding we use to store memories—especially considering that we tend to remember concepts and forget irrelevant details. If these neurons are lacking, the ability to generate abstractions may be limited, leading to pathologies such as autism or characters like Funes. (ibid. 611)

Funes’ condition is possible, then, in a purely organic way, and does not necessarily require the intercession of either poetic license or an electronic processor. Physicist Matthieu Ricard would appear to agree with Quian Quiroga’s diagnosis; if an injury to the cerebral cortex were sustained, a person could potentially shed their sense of self without losing their ability to process sensory information (or, again, could have this ability augmented, according to Quian Quiroga).

> If the memory was dependent on an “ego,” then those who freed themselves from the sense of having an ego would become amnesic! We must avoid confusing the conceptual notion of an “ego” with the stream of individual consciousness. The lack of an “ego” doesn’t stop the workings of memory that is imprinted in the cerebral system and that modifies its own gross consciousness. (Ricard 179)

Is a memory system without an ego not simply a computer, though? If a cyborg can be defined as essentially an advanced computer—an incomplete, *artificial* intelligence—ensconced in organic tissue, then we might still abstractly consider Funes to be a literary cyborg.

> Even Calvino’s Palomar can be seen through this lens as an inversion of the cyborg, or at the very least as a human that strives to become a computer. Assailed and harrowed by a
persistent sense of anxiety and existential dread, Palomar is finally released from these human sensations through death. While we have already cited this moment in a previous discussion, it bears repeating now: “[Palomar] decides that he will set himself to describing every instant of his life, and until he has described them all he will no longer think of being dead. At that moment he dies.” (Calvino 126) In an exercise identical to that of Funes – the emotionless description of all memories, objects and events – Palomar destroys his ego, with the cost of also terminating his own life. In striving to become un-human, he annihilates himself, never to live in the same beige limbo that Funes knew. Funes, as well, finds his release in death – a death that is the only reminder to the reader that he is human, after all: “Ireneo Funes died in 1889 of pulmonary congestion.” (CF 137)

We must also recall a 1967 lecture by Calvino entitled “Cybernetics and Ghosts,” both for its explicit invocation of cybernetics as well as for its proposed equivalence between the human brain and a computer. He begins with a comparison between mathematics and narrative that is very germane to our own argument: “On an equal level of civilization, the operations of narrative, like those of mathematics, cannot differ all that much from one people to another, but what can be constructed on the basis of these elementary processes can present unlimited combinations, permutations and transformations.” (Uses of Literature 6) As a human being employs his brain for the task of creating such combinations and connections, he can “feel the rapid passage of signals on the intricate circuits that connect the relays, the diodes, the transistors with which our skulls are crammed.” (ibid. 8)

After invoking the work of the mechano-poetic Oulipo group, Calvino finally makes the leap into the philosophical by asking a pertinent question related to artificial intelligence:

Having laid down these procedures and entrusted a computer with the task of carrying out these operations, will we have a machine capable of replacing the
poet and the author? Just as we already have machines that can read, machines that perform a linguistic analysis of literary texts, machines that make translations and summaries, will we also have machines capable of conceiving and composing poems and novels? (ibid. 12)

We now know the answer to this question to be resoundingly affirmative – machines currently produce pulp novels and romances according to prescribed formulas and vocabulary banks, and human beings read these works often without any knowledge that they have been produced through the collaboration of a mechanical/combinatorial process and a human editor. This is not the “literature” that Calvino intends, however; he clarifies, stating that

The true literature machine will be one that itself feels the need to produce disorder, as a reaction against its preceding production of order: a machine that will produce avant-garde work to free its circuits when they are choked by too long a production of classicism. In fact, given that developments in cybernetics lean toward machines capable of learning, of changing their own programs, of developing their own sensibilities and their own needs, nothing prevents us from foreseeing a literature machine that at a certain point feels unsatisfied with its own traditionalism and starts to propose new ways of writing, turning its own codes completely upside down. (ibid. 13)

In the modern day, as was hinted at in the examples of cyborgs in popular fiction and film cited earlier, our culture has imagined an analogous cybernetic self-awareness in the form of Skynet, the global military defense matrix that activates itself and annihilates human life in the Terminator series. While Calvino’s ideal for cybernetic writing is far less pessimistic, the process leading to both outcomes is the same – an artificial intelligence reaches and passes the threshold for self-awareness and, like HAL in 2001: a Space Odyssey, becomes spontaneously able to modify its own code in order to make itself more efficient and creative (in Calvino’s example) or in order to ensure its own survival (in the case of Skynet).

While the militant scenario is certainly titillating, we must remain focused on Calvino’s more literary concerns; he concludes, after much analysis, that the standard for an author-cyborg
that might replace the human author would be extremely high, with a requirement that the cyborg also possess an ingrained societal awareness and personal history.

Literature is a combinatorial game that pursues the possibilities implicit in its own material, independent of the personality of the poet, but it is a game that at a certain point is invested with an unexpected meaning, a meaning that is not patent on the linguistic plane on which we were working but has slipped in from another level, activating something that on that second level is of great concern to the author or his society. The literature machine can perform all the permutations possible on a given material, but the poetic result will be the particular effect of one of these permutations on a man endowed with a consciousness and an unconscious, that is, an empirical and historical man. It will be the shock that occurs only if the writing machine is surrounded by the hidden ghosts of the individual and of his society. (ibid. 22)

The human and the cyborg appear to engage in the same processes when it comes to simply transcribing a narrative or poem, with the distinction only becoming apparent at the secondary, anagogical level of the text. This is not impossible – as artificial intelligence becomes increasingly refined and quantum computers come to replace the binary machines of the current age, the possibility of imbuing one of man’s creations with a human-like psyche multiplies exponentially.

More still can be said of Calvino’s fascination with the fusion of man and machine by way of a brief analysis of the appearance of computerized writer and reader of If on a Winter’s Night a Traveler... “Lotaria,” a university student who is writing a thesis on the novels of the narrator, Silas Flannery, informs the writer that the way in which she “reads” his works is opposed to the traditional way in which her sister Ludmilla reads them – a method that Lotaria deems “passive,” as well as “escapist and regressive.” (Calvino 185) Instead of wasting time on a linear reading of a book, Lotaria explains that “a suitably programmed computer can read a novel in a few minutes and record the list of all the words contained in the text, in order of frequency,” thereby granting her an “incalculable saving of time.” (ibid. 186) She then simply scans these
lists and pieces together an approximated narrative in her own mind. Such a cybernetic reading, which is nothing more than an electronic process that is subsequently and selectively audited by a human mind, will necessarily yield a conceptual result that differs from the one granted by a traditional reading. Lotaria, however, would not agree – she states that one need only “head straight for the words richest in meaning; they can give [the reader] a fairly precise notion of the work.” (ibid. 186)

Flannery is both perplexed and disappointed by Lotaria’s style of reading, and begins to formulate a way of writing that might be better matched to this non-ideal reader.

Now, every time I write a word, I see it spun around by the electronic brain, ranked according to its frequency, next to other words whose identity I cannot know, and so I wonder how many times I have used it, I feel the whole responsibility of writing weigh on those isolated syllables, I try to imagine what conclusions can be drawn from the fact that I have used the word once or fifty times… Perhaps instead of a book I could write lists of words, in alphabetical order, an avalanche of isolated words which expresses that truth I still do not know, and from which the computer, reversing its program, could construct the book, my book. (ibid. 189)

Quintessentially postmodern, Flannery’s proposal would annihilate the authorial process as we know it, creating instead a system of combinatorial genesis that was hinted at in “Cybernetics and Ghosts” and Calvino’s experimentations with the Oulipo group. That this crisis is framed within Calvino’s fragmented and abortive narrative only serves to redouble the confusion and sense of meaninglessness that such a technique would present.

While in general the study of post-human science (and fiction) has been devoted to the anatomical fusion of man and machine, it has also, at times, addressed the consequences of the eventual genesis of a race of omniscient cyborgs: if all men, through technology, come to know all things, then isn’t the idea of “all men” reduced to the same idea as just “one man?” Jean Baudrillard hinted at this concept in 1981, in *Simulacra and Simulation*: 

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Already, biophysioanatomical science, by dissecting the body into organs and functions, begins the process of the analytic decomposition of the body, and micromolecular genetics is nothing but the logical consequence, though at a much higher level of abstraction and simulation – at the nuclear level of the command cell, at the direct level of the genetic code, around which this whole phantasmagoria is organized… From the point of view of cybernetics and computer science, [each single organ] is the smallest undifferentiated element, each cell of a body becomes an “embryonic” prosthesis of this body. (Baudrillard 98)

Herbrechter and Umansky connect this same “embryonic” redundancy – yet another example of mise en abyme – to Borges: “The topos that ‘one man is all men,’ that one human is both the archetype, essence, and ‘end’ of all humanity is ubiquitous in Borges’s fictions and critical essays.” (Herbrechter 18) We have cited “Pierre Menard…” as proof of this, but more evidence can be found in “The Immortal” (in which, due to their immortality and the cyclical nature of the universe, all men have seen and known all things, thereby rendering them all identical copies of one man) and “The Cult of the Phoenix” (in which a secret cult has as its member every single human being in the world, and these members “resemble every man in the world.” [CF 172]). Borges and Calvino have indeed employed such post-human imagery throughout their works in order to address our shared humanity and to call into question the validity of our own senses of self.

Some concluding thoughts on the future of the literary and physical post-human can be found in Brian Greene’s The Hidden Reality –

You engage the world through your senses, which stimulate your brain in ways your neural circuitry has evolved to interpret. If someone artificially stimulates your brain so as to elicit electrical crackles exactly like those produced by eating pizza, reading this sentence, or skydiving, the experience will be indistinguishable from the real thing. Experience is dictated by brain processes, not by what activates those processes. Going a step further, we can consider dispensing with the sloppiness of biological material altogether. Might all of your thoughts and experiences be nothing more than a simulation that leverages software and circuitry sufficiently elaborate to mimic ordinary brain function? Are you convinced of the reality of flesh, blood, and the physical world, when actually
your experience is only a crowd of electrical impulses firing through a hyper-
advanced supercomputer? (Greene 323)

It is almost as if Greene has harvested these words directly from any one of the stories we have encountered in this study of Calvino and Borges, so often have these authors called into question the “realness” of human experiences. Greene goes on, tracing a line to the inevitable moment in which supercomputers will finally overtake the processing power of the human brain.

One broad-brush prognosis holds that the surpassing of brainpower by computers will completely blur the boundary between humans and technology. Some anticipate a world run rampant with thinking and feeling machines, while those of us still based in old-fashioned biology routinely upload our brain content, safely storing knowledge and personalities in silico, complete with backup drives, for unlimited durations… A central assumption of this perspective is that conscious thought is not overlaid on a brain, but rather is the very sensation generated by a particular kind of information processing. Whether that processing happens within a three-pound biological mass or within the circuits of a computer is irrelevant. (ibid. 325-6)

The material out of which our brains are fashioned, it would seem, is of no consequence – if our minds are simply organic computers, they carry, like computers made of silicon and steel, an upper limit on processing speed and efficiency. If the physical composition of the brain were to eventually become more inorganic than organic, Greene’s statement suggests that what we think or feel may or may not necessarily change. If our ability to understand and manipulate the brain evolves concurrently, then anything is possible:

Although we are still very far from mastering this application of quantum mechanics, researchers have estimated that a quantum computer no bigger than a laptop has the potential to perform the equivalent of all human thought since the dawn of our species in a tiny fraction of a second… Generate circuits that carry the right information and you’ve generated parallel realities that are as real to their inhabitants as this one is to us. (Hidden 329-330)

It remains to be seen if science will truly free us from the limitations of human consciousness; in a more dystopic turn, we could instead have our own, individual realities replaced with convincing simulations, much like that of the magician in Borges’ “The Circular Ruins.”
Herbrechter and Umansky have noted that in such a situation, “the system generating a reality is shown to be a part of the reality it makes…” (Herbrechter 18-19) Borges and Calvino have both repeatedly illustrated this concept through their fictions, which once again conclusively locates them at the intersection of science and literature.

**Conclusion: Science-as-fiction**

The primary goal of this study has been to isolate and analyze the many appearances of scientific and mathematical themes in the works of Jorge Luis Borges and Italo Calvino, with the intention of drawing together both fields into one complementary and interdisciplinary continuum. The research undertaken toward this end has yielded an enormous number of connections and shared concepts between these disciplines, most of which have helped to illustrate both the methodological underpinnings of literary fiction as well as the creative and imaginative origins of many scientific theories. In the last decade, though, the scientific imagination has shown itself to be on equal footing with that of the literary. Advances in the studies of dark matter, black holes and the unifying theories of quantum physics have presented us with conjectures and explanations that, to the layman and physicist alike, are virtually indistinguishable from works of fiction.

*Dark matter* – a substance whose probable existence was derived from Einsteinian calculations toward the total mass of the universe – is a popular topic in the scientific news of the current day. While the calculations involved in theorizing its existence (along with the existence of its kinetic counterpart, *dark energy*) are stentorian in nature, Brian Greene – a man who, like his contemporary Neil DeGrasse Tyson (and Carl Sagan before them) has successfully made
scientific knowledge palatable and intriguing to an increasingly distracted populace – has
provided us with a suitable introduction. He tells of current theorizations suggesting that
a mere 5 percent of the universe’s heft comes from the constituents found in
familiar matter – protons and neutrons (electrons account for less than .05 percent
of ordinary matter’s mass) – while 25 percent comes from dark matter and 70
percent from dark energy. But there is still significant uncertainty regarding the
detailed identity of all this dark stuff… So, if not protons and neutrons, what
constitutes the dark matter? As of today, no one knows, but there is no shortage of
proposals. The candidates’ names run the gamut from axions to zinos, and
whoever finds the answer will surely pay a visit to Stockholm. That no one has
yet detected a dark matter particle places significant constraints on any proposal.
The reason is that dark matter is not only situated out in space; it is distributed
throughout the universe and so is also wafting by us here on earth. According to
many of the proposals, right now billions of dark matter particles are shooting
through your body every second, so viable candidates are only those particles that
can pass through bulky matter without leaving a significant trace. (Fabric 432-3)

Without slipping into a well-warranted hysteria, we might calmly re-state this explanation in
more simplistic terms: according to our current calculations, ninety-five percent of the universe
we inhabit is not only invisible, but imperceptible – and yet it continues to act upon us,
constantly. Conversely, this statement also therefore introduces the disturbing proposition that
human beings are only aware of five percent of the universe in which they live every day of their
existence. A statement by DeGrasse Tyson echoes our understanding of these implications:

At the end of the day, no matter how confident we are in our observations, our
experiments, our data, or our theories, we must go home knowing that 85 percent
of all the gravity in the cosmos comes from an unknown, mysterious force that
remains completely undetected by all means we have ever devised to observe the
universe. (Degrasse Tyson 20)

Once again, it must be repeated that these are not statements being made in the privileged towers
of literary criticism or fiction – these are scientific statements. That the current discourse in the
“hard” sciences has effectively introduced a level of doubt and uncertainty that is equal to (or
possibly greater than) that which is typically reserved for the hypothetical, un-empirical “soft”
sciences is significant, although not wholly unexpected. After all, many thinkers – Pascal, Gödel,
Heisenberg, to wit – have historically debated the solidity of science’s claim to present any sort of universal or absolute truth.

Further examples of scientific concepts that test the borders of verifiability are those of String Theory and M-Theory. While not brand-new concepts (as String Theory was first introduced in the late 1960s), they are still hotly debated and their subtle, infinitesimally-tiny components certainly tend toward the whimsical. Greene’s summary of String Theory is simple, yet suggestive of the full magnitude of this concept:

We’ve seen that the standard view, prior to string theory, envisions nature’s fundamental ingredients as point particles – dots with no internal structure – governed by the equations of quantum field theory. With each distinct species of particle is associated a distinct species of field. String theory challenges this picture by suggesting that the particles are not dots. Instead the theory proposes that they’re tiny, stringlike, vibrating filaments… Look closely enough at any particle previously deemed elementary and you’ll find a miniscule vibrating string. Look deep inside an electron, and you’d find a string; look deep inside a quark, and you’d find a string. With even more precise observation, the theory argues, you’d notice that the strings within different kinds of particles are identical, the leitmotif of string unification, but vibrate in different patterns. (Hidden 91)

What is being posited, then, is that the basis of the entire universe – the smallest possible building-block of reality – is a single variety of one-dimensional “string,” whose ability to vibrate in various patterns and at various frequencies has led to the existence of larger and more complex forms of matter. No one has ever observed such strings, nor can anyone hope to in the foreseeable future – they simply exist as the abstractions of intricate mathematical exercises. This lack of verifiability has not stopped physicists from building further theories upon its framework, however; M-Theory, which was drafted as a solution to the conflicting existence of no fewer than five separate strains of String Theory, presupposes the consistency and verity of what cannot yet be proven or seen.
In the 1980s, theorists realized that there was not one string theory, but rather five different versions… All five include the same gross features – vibrating strings and extra spatial dimensions… If perturbative calculations in one string theory can’t be undertaken because that theory’s coupling is too large, the calculations can be faithfully translated into the language of another formulation of string theory, one in which a perturbative approach succeeds because the coupling is small. Physicists call the transition between naïvely distinct theories *duality*. It has become one of the most pervasive themes in modern string theory research. By providing two mathematical descriptions of one and the same physics, duality doubles our calculational arsenal. Calculations that are impossibly difficult from one perspective become perfectly doable from another… All five string theories are linked through a network of such dualities. Their overarching union, called M-theory…combines insights from all five formulations, stitched together through the various duality relationships, to gain a far more refined understanding of each. (Greene *Hidden Universe* 124-27)

While this alone seems perfectly reasonable and barely adds any credence to our suggestion that science may approach fiction as it makes increasingly bold conjectural leaps, Greene’s next statement makes the connection apparent:

An allied revelation, just as flabbergasting to those who’d spent the better part of their professional lives working on the subject, was that the number of spatial dimensions the theory requires is not actually nine. It’s ten. And if we fold in the dimension of time, the total number of spacetime dimensions is eleven. (ibid. 128)

Eleven spacetime dimensions are therefore required in order to resolve the world according to the equations of M-Theory, which is itself built upon the assumption that these sub-nanoscopic, curled-up dimensions are populated exclusively by invisible, vibrating strings. While these theories enjoy a strong following in the scientific world and, to date, represent humanity’s best guess as to the true nature of the universe, we must ask the following question: if the main explanation of the nature of the universe is conjectural, based on incomplete proofs and is impossible to conclusively verify, how exactly can science be wholly distinct from fiction? Is the distance between them found in their methodological approaches? Perhaps not, according to what we have seen of Calvino’s and Borges’ exercises in confronting the metaphysical and the impossible through soundly logical frameworks. As for their foundational precepts… well,
Gödel’s damning assessment of the incompleteness of any system that is formed by entities existing inside said system all but reduces humanity’s scientific and fictive enterprises to their lowest common denominator: the imagination.

All in One Point – A Conclusion

In order to draw this considerable study to a close, a measure of recapitulation will, of course, be necessary. However, rather than attempt to distill such an enormous body of complex scientific thought into unsuitably brief passages, we will instead engage in a final summation of the underlying theme of this entire dissertation: the ideal of intellectual interdisciplinarity that is embodied in the works of Italo Calvino and Jorge Luis Borges. By emphasizing once more the advantageous viewpoint permitted by an inclusive and manifold approach to human knowledge, we will hopefully provide a coherent and honed conclusion to this study.

Calvino’s trajectory from his earliest works – a body of writing largely preoccupied with political and revolutionary concerns – to his later, scientifically-informed discourses is well-documented. In her work on Calvino’s scientific themes, Kerstin Pilz notes the peculiar “intellectual itinerary from his debut as a neorealist writer, which is followed by a period of crisis and a rethinking of theoretical positions, to the mid-Sixties when he reaches a point of arrival by turning explicitly to science and proposing literature as an interdisciplinary discourse.” (Pilz VXII) According to Pilz – an expert on this topic, and a scholar to whom our own research is greatly indebted – Calvino was clear in defining fiction’s links to other disciplines; he expressed in several essays that “literature is fundamentally connected with other forms of knowledge and thinking… It is science, not the new avant-gardes, that offers ‘replenishment’ for a literary genre that had ‘exhausted’ itself.” (ibid. 18-19) She confirms that Calvino’s greatest
influences – Queneau, Borges and Carroll – “likewise were inspired by a scientific approach that privileged a mathematical sense of composition and mental abstraction.” (ibid. 56) Calvino’s place within his own literary epoch is also contextualized by Pilz, along with a reiteration of science’s primacy throughout his mature oeuvre.

For Calvino the end of “mourning” for a lost harmony comes through a turn toward science, notably information science, in order to derive from it a model that would lend unity to what has become fragmented. As becomes clear with the formal organization of Le Cosmicomiche, Calvino favours short texts (already evident in Marcovaldo). The short story or novella makes his novels into infinitely connectable matrices of self-contained stories. The short text, or petit récit is for Lyotard characteristic of the postmodern episteme, where the totalizing grand narratives of legitimation of knowledge have been replaced with “little narratives” which he sees as “the quintessential form of imaginative invention, most particularly in science.” (ibid. 23)

Even the literary form employed by Calvino is drawn from science’s well, proving once again that his interdisciplinary bearing is truly one of the defining aspects of his creative output.

Borges is also found at the intersection of numerous fields of study and academic disciplines; his fictional experiments bundle together extraordinarily varied breeds of philosophy and science, as Floyd Merrell notes:

> What I do suggest is that Borges, like all writers, participates in an exceedingly complex cultural matrix. Out of this matrix, and revealed in the culturally aware intellectual’s work, one finds the product of a general climate of opinion…which potentially brings about a convergence of thought and speculation from various fields of endeavor… I submit [that] leading intellectuals from all walks are sensitive not only to the state of affairs in their chosen field of endeavor, but to contiguous fields as well, and they have the skill to incorporate this awareness into their work, at times even to bring about changes. Borges’ metaphysical stories and essays are such an imaginative response to the complexities, uncertainties, and ambiguities implicit in many contemporary modes of thought and conduct. (Merrell XIV)

This “matrix” is formed through the collision of Borges’ exceptionally diverse intellectual interests, functioning as a level testing ground within which the author may call into question literally any aspect of human knowledge, exposing it to arguments and theorizations borrowed
from wholly unrelated disciplines. In *Fiction Refracts Science*, Allen Thiher demonstrates a
similar understanding of experimental literary methodology:

> If some works of fiction can be called thought experiments – and not simply
metaphorically – it is because some writers see their minds to be something like
private laboratories wherein relationships and variables taken from the world can
be imaginatively changed, and the putative outcomes of these transformations
predicted in the imagination. These outcomes are then depicted experimentally in
the fiction that ensues. Perhaps not all experimental writers self-consciously
conceive of their work as thought experiments, but many do: Borges, Queneau,
Serraute, Robbe-Grillet, and Calvino are cases in point. (Thiher 218)

Zooming in on Borges specifically, Thiher goes on to define the complicating goal of Borges’
creative exercises:

> Especially in Borges, fiction takes the form of self-reflexive experiments that
flaunt the rules of the game. These fictions often ironically demonstrate their own
futility as self-contained forms of play. They also point up the near mathematical
nature of fictions that self-consciously display the axioms generating them. With
these experiments Borges aims at demonstrating the aporia of scientific theory or,
more generally, the paradoxes of any self-referential epistemic project. (ibid. 219-
220)

While working to dismantle his reader’s faith in the sacred foundations of human knowledge,
Borges simultaneously equalizes the generative processes of science and fiction, lending the
impression that they are one and the same. This interdisciplinary statement echoes one of Werner
Heisenberg’s most well-known quotations (cited in Ricard, 4): “I consider the ambition of
overcoming opposites, including also a synthesis embracing both rational understanding and the
mystical experience of unity, to be the *mythos*, spoken or unspoken, of our present day and age.”
Bearing this in mind, we can also restate the equivalence between science and fiction that has
been recognized by literary critics and scientists alike. In an article appropriately entitled “Poetry
and Science,” Peter Forbes, a science writer based at the University of London, makes a
representative claim for acknowledging the “poetic” as it can be found in nature.
“Poetry and Science” at first suggests poems about science, but it can also help us to look at science from a different angle. Reading a scientific paper that opens up a new field has a similar effect to reading a significant new voice in poetry for the first time: you are not sure where it will lead. Take, for example, the paper by Joanna Aizenberg and colleagues which revealed the single-crystal microlens array in the brittle star Ophiocoma wendtii. The structure of the array itself is beautiful: it resembles the sort of organic blob architecture that is now fashionable. Each lens is microengineered to an astonishing degree: it corrects the spherical aberration of light by means of the classic Huygens/Descartes reversed-curve rear surface, and the precise alignment of the crystal excludes double-reflection effects. Then there was the synthetic DNA octahedron that featured on the cover of Nature in February 2004. I claim these finds as poetry. (Forbes 321)

If the “poetic” can simply be defined as a creative exercise (natural or man-made) that generates or highlights any form of intellectual, scientific or philosophical novelty, then locating the poetic within scientific concepts should not ever be more difficult than would be finding it in works of fiction.

A final thought on bridging disciplines can be constructed by juxtaposing several succinct, but powerful quotations from several of the scholars and critics we have encountered over the course of this study. The first comes from Allen Thiher, who cautions that “science is almost always involved in any depiction of madness.” (Thiher 265) A similar problematization of scientific “truth” is presented by Matthieu Ricard, who appears to scold the Palomars of the world: “Like the prime cause, the idea of a closed circle is just an escape route for people who can’t bear the idea of infinity.” (Ricard 51) Michio Kaku, as well, casts a shadow on humanity’s typically hopeful conception of science: “The laws of physics tell us what is possible, not what is practical.” (Hyperspace 247) While these statements may initially come across as cynical or fatalistic, they need not be understood as such – if fiction and science were to work in concert, as was proposed by Calvino and demonstrated by Borges, then concepts that seem hopelessly bleak could instead be harnessed as fierce catalysts for human creativity.
Ultimate unknowability is the shared fate of all human inquiry. Science and fiction are both human exercises, and both are equally limited by mankind’s inability to observe itself from outside of its own paradigm. So much can never be known – Brian Greene confirms as much in *The Fabric of the Cosmos*:

We can’t ever know the exact location and exact velocity of even a single particle. We can’t predict with total certainty the outcome of even the simplest of experiments, let alone the evolution of the entire cosmos. Quantum mechanics shows that the best we can ever do is predict the probability that an experiment will turn out this way or that. And as quantum mechanics has been verified through decades of fantastically accurate experiments, the Newtonian cosmic clock, even with its Einsteinian updating, is an untenable metaphor; it is demonstrably not how the world works. (Greene 79)

Kerstin Pilz concurs, adding a reminder of Calvino’s prescient sagacity –

As Heisenberg has persuasively argued: “Natural science does not simply describe and explain nature; it is part of the interplay between nature and ourselves; it describes nature as exposed to our method of questioning.” Thus both science and literature offer fictions about the relationship between the subject and the world, and while, as Calvino noted, it was in fact literature that problematised the observer’s subjectivity before science acknowledged its own limitations, literature can adopt the scientific method of minute observation and precise description in an attempt to reassess and possibly renew the relationship between human beings and the cosmos. (Pilz 63)

Regarding Calvino’s function as a writer of fiction who has been fed on science, she also asserts that “by humanizing the cosmos to the extreme he makes familiar and thus accessible what is not, nor perhaps can ever be.” (ibid. 29) The function of any writer is not to resolve the limitations of human knowledge and consciousness, but rather to continue to create in spite of such limitations, with freedom and ingenuity. As for Borges’ function, Floyd Merrell’s words will suffice: “Perhaps, in the final analysis, Borges’ fictions, or any other fictions for that matter, are in some respects not necessarily any less ‘real’ than the scientist’s theories and models, derived from her freely wandering mind rather than directly from the ‘facts’ before her”. (Merrell 87) Rather than considering fiction and science to be equally “real” – a statement that
categorically cannot ever be proven, and that will lead to unending disappointment – it may be more advantageous for us to consider them as equally “false,” thereby releasing both from any expectation of absolute coherence and joining them, along with all other forms of human knowledge, into a single, larger continuum of ideas that carries exponentially greater generative potential.

We will conclude by positing that, according to our research, science has in certain ways become fiction. It is our hope that, in the spirit of Italo Calvino and Jorge Luis Borges, both of whom worked so tirelessly toward an interdisciplinary ideal, fiction might in its own turn become science, thereby empowering humanity to think, theorize and dream ever more strangely, and ever more magnificently.
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