TRANSCENDENTAL MINDS AND MYTHICAL STRINGS:

THE EMERGENCE OF PLATONISM IN MODERN PHYSICS.

by

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ABSTRACT

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String theory has captivated the theoretical physics community for nearly twenty five years. Despite the optimism that string theory will lead physicists to a deeper understanding of the universe, no unique theory has emerged from a long series of conjectures and loosely related facts. While the Large Hadron Collider is set to start running experiments this year in Geneva, it is doubtful that its observations will be able to confirm or reject string theory either. String theory has emerged in a rare period in the history of physics, during which experimental thresholds have been met and theory seems to break down above that threshold. I argue that an emphasis on mathematical symmetry and harmony in string theory physics is part of a Platonic metaphysics tradition that emerged in previous epochs in the history of physics when experiment or theory has failed. However, in contrast to other periods when Platonic metaphysical ideas have been helpful to resolve dilemmas in physics, string theorists have allowed themselves to become estranged from experiment as well as other viable theoretical research programs in contemporary physics.

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Chapter I. In Search for Supersymmetry and Massless Space

Why are the world's wealthiest nations spending billions of dollars and dedicating the careers of their most talented physicists and engineers to the construction of the largest particle accelerator of all time? If you guessed, "to probe the smallest, most fundamental particles in the cosmos," you would be right. Later this year, the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN), outside of Geneva, should be fully functional for experiments that project bunches of protons at each other at near-light speeds and with energies in the range of several trillion electron-volts[1] (tera-electron-volts or TeVs). The collisions, or events in the physics jargon, will produce a soup of highly energetic particles once every twenty-five nanoseconds, requiring a massive array of supercomputers to filter out the leagues of meaningless data produced by the collisions and organize the "good" data into sets for analysis by physicists.[2]

The primary motivation for the LHC is to probe the TeV energy scale. At this energy, physicists hope to discover the Higgs boson[3], a theoretical particle that is used to explain how the fundamental particles of nature acquire mass.[4] The Higgs particle is the single remaining particle of the so-called Standard Model of the Universe whose

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[1] An electron-volt is the amount of energy required to move an electron across a potential difference (voltage) of one volt.

[2] Graham P. Collins. "Large Hadron Collider: The Discovery Machine" *Scientific American.* (February 2008): 39-45.

[3] Quantum mechanics treats particles in the Universe differently according to an intrinsic property called spin. Particles that have *integral spin* (0, 1, 2 …) are called bosons and particles that have half-integer spin (1/2, 3/2, 5/2 …) are called fermions. Cf. Roger Penrose. *The Road to Reality.* (New York: Alfred A. Knopf, 2004) 594-598.

[4] Standard Particle Physics Theory describes interactions between massless particles very well. By adding mass, the theory makes predictions that contradict observed phenomena. As a result, the Higgs mechanism for mass acquisition was adopted into the Standard Model of the Universe. Cf. Gordon Kane. *Supersymmetry.* (New York: Da Capo Books, 2000) 28-29.

existence has not been confirmed. Yet with its utmost importance to a complete physical description of the cosmos, there exists no working theory that predicts above what threshold range of energies it will be found, if at all. Some theories that predict the Higgs' existence suggest that through interactions with virtual particles – ones permitted by quantum theory – the Higgs boson could require up to 10^{16} TeV of energy in order to be produced.[5] Other theories propose a much lower value – 250 GeV – for the Higgs boson threshold. If this is correct, then the LHC will certainly be able to determine whether Higgs particles exist around that energy threshold when it is fully functional. However, the theories that anticipate the lower threshold energy for the Higgs boson also require the existence of extra symmetries in our universe to stabilize the Higgs mass. Such symmetries have never been confirmed experimentally.[6]

Aside from the Higgs particle threshold energy problem, the other major problem that physicists are thinking about is the incompatibility of Quantum Field Theory (the theory that describes strong, weak and electromagnetic field interactions with matter) and General Relativity (Einstein's Theory of Gravity). Gravity is 10^{32} times weaker than the next weakest force, the aptly named Weak Force.[7] This makes it virtually impossible to detect its effects at the quantum level where the stronger forces dominate – this distinction is referred to as the Hierarchy Problem.[8] Also, Einstein's General Relativity

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[5] This energy scale is not attainable by present particle accelerator technologies, and is not expected to become possible even in the distant future.

[6] These conjectured symmetries, for example, take every boson and fermion in the universe and pair them with a new particle of the opposite type but the same mass, creating a symmetrization of boson-fermion pairs. At our low-energy limits, these so-called "supersymmetric partners" are elevated to higher masses and the symmetry between pairs is broken. Quantum effects of this symmetry are supposed to suppress the mass of the Higgs boson, bringing it within reasonable energy thresholds. Cf. Lisa Randall. *Warped Passages.* (New York: HarperCollins Publishers, 2005) 257-269.

[7] Randall, 250.

[8] Kane, 117.

describes gravitational effects through the warping of space-time by mass and energy.[9] Physicists encounter difficulty trying to formulate a quantum theory of gravity because of the unwieldy nature of gravitational waves, through whose interactions with matter and other gravitational waves space-time can warp at every single infinitesimal point – the infinite number of parameters involved in describing gravity as a quantum field theory necessarily introduces instabilities to the theory. In order for a complete theory of gravity to be established by principles of Quantum Field Theory, it must include: (1) a massless spin-2 particle, i.e. the graviton, which would communicate the gravitational force and (2) elicit the same predictions as General Relativity at the classical approximation. So far experiments have not discovered any gravitons, and attempts to incorporate a Quantum Field Theory that includes gravitons make predictions that are incompatible with current observations as well as predictions made from General Relativistic calculations.[10]

With no more experimental evidence toward a solution of the threshold and hierarchy problems described above, theoretical physicists have spent the past 25 years working on new theories of the Universe, all trying to unify the laws of physics through the expression of new theoretical mechanisms. There were theories of Supersymmetry that predict the existence of "superpartners" for both fermions and bosons making each type of particle interchangeable with the other.[11] A theory known simply as the Grand Unification Theory (GUT) suggested that above a very high energy threshold, all the forces in the cosmos come together as one unified force, suggesting that all of the forces in Quantum Field Theory were related by a high energy symmetry and could be

[9] Three dimensions of space + 1 dimension of time.
[10] Lee Smolin. *The Trouble with Physics* (New York: Houghton Mifflin Company, 2006) 80-98.
[11] Cf. Kane, *Supersymmetry*.

interchangeably related above the GUT energy threshold.[12] Either of these theories can be seen as an extension of the Standard Model into energy thresholds that have not yet been produced and as a result make no changes to the "low energy" description of the Universe that can presently be attained by particle accelerators. However, neither GUT theory nor Supersymmetry has any applicability to the problem of realizing a complete theory of physical interactions that would also explain gravity's weak influence on the quantum domain.[13] New theoretical models have mostly eliminated GUT as a viable extension to the Standard Model and, as suggested previously, the particles of Supersymmetry are predicted to exist at much higher energy thresholds than are currently available to probe.[14]

Despite the shortcomings of previous theoretical insights beyond the Standard Model, one theory emerged contemporary to Grand Unification and Supersymmetry that made an even stronger break from Standard Model physics – this theory is called Superstring Theory. Superstring theory was proposed as a super-unification of general relativity and the standard model, bringing both the quantum theory of forces and relativistic theory of gravity together into one meta-theory. By replacing all fundamental particles of Quantum Field Theory with open and closed strings, Superstring theory claims that particles emerge from resonant frequencies of one-dimensional vibrating strings. It also makes the revolutionary claim that the space in which they move – the space of our cosmos - extends into extra hidden dimensions that we can neither experience directly nor test for their effects in contemporary experimental setups. Despite

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[12] Peter Woit. *Not Even Wrong* (New York: Basic Books, 2006) 95-97.
[13] Supersymmetry and GUT both deal with the three forces and particles of the Standard Model; gravity, which is the subject of general relativity, was largely ignored in these theoretical endeavors. Cf. Smolin, 78.
[14] Smolin, 63-65.

the unbelievable claims that rest at the center of string theory, physicists got hooked by the theory's single-most encouraging prospect: string theory was the only unification theory at the time that could also explain a theory of Quantum Gravity – its original formulation had the unpredicted property of requiring the existence of a massless spin-2 particle, for which the graviton was the only possible candidate.

By 1984, the date of the so-called first superstring revolution, the majority of theoretical physicists became so convinced that string theory would lead to fundamental solutions about how general relativity and quantum theory – the two revolutions of the 20th Century – could be related that they overwhelmingly relinquished their current research endeavors to take up string theory. Young scientists who obtained their Ph. D. in theoretical physics following the first superstring revolution predominantly began string theorists themselves. The climate of the field was characterized by the physicists' impression that they had stumbled upon a theory that was so elaborate and fundamental that only hours and hours of devoted research stood between them and the interpretation of string theory that would explain all known physics.[15]

Despite its strong initial surge to solve the biggest problems in contemporary physics, in many ways superstring theory has created more problems than it promised to solve. First, this is because of the smallness of the strings, the energy threshold required to probe or identify them, or any of their direct effects lies far beyond what is reasonably possible in any future high energy particle collider. Additionally, the extra dimensions must be justified in some way that would do more than agreeing with observations confirming the Standard Model – new observations must lead to new effects that are

[15] Randall, 296-297.

legitimately correlated to the extra-dimensionality of space. So far, two additional problems have plagued extra-dimensional String Theories: (1) there is an infinite number of ways to compactify (curl up) the extra dimensions, which makes it virtually impossible to determine a unique description for how or why the dimensions are hidden and (2) each distinct scenario of curling up the extra dimensions leads to a unique set of physical laws, suggesting an infinite landscape of cosmological scenarios. In order for String Theory to predict the "right" scenario – in order for our universe and the particles and forces that exist in it to obtain their observed values, a new set of parameters would have to be proposed in order to choose our reality scenario from the 10^{500} other possibilities predicted by String Theory.

Despite the many additional hardships imposed on theoretical models by Superstring Theory, its popularity as a discipline has grown considerably since the inception of its most current formulation in 1984. Since then, University Physics Positions have overwhelmingly been taken over by theoretical physicists studying String Theory rather than physicists studying other theoretical disciplines in particle physics and cosmology. This fact is also evident in the disproportionately large number of published articles on String Theory in peer-reviewed scientific journals.

Criticism of the present imbalance was first raised in two eye-opening books that offer detailed criticism of String Theory. *The Trouble with Modern Physics* (2006) by Lee Smolin grapples with the fundamental unsolved problems of modern physics during this period of String Theory's dominance of the field despite a longstanding absence of experimental findings to test its conjectures.[16] Also published in 2006 is Peter Woit's *Not*

[16] Lee Smolin. *The Trouble With Physics* (New York: Houghton Mifflin Company, 2006).

Even Wrong, which questions whether String Theory can even be considered a scientific pursuit, or if it is just applied mathematics being used toward a more unifying theory, regardless of its predictive ability.[17] The contemporaneous release of these two bold texts should begin open discussion of string theory to open its history, successes and drawbacks to analysis and critique. This thesis seeks to enter into this live debate.

The foundational work done by Professors Smolin and Woit has inspired the present thesis, which can best be described as a philosophical analysis of string theory. By illustrating the development of superstring theory into its most recent form, the landscape of superstring theory, I will argue that a Platonic movement has emerged in contemporary theoretical physics, marked by an effort to seek out unification and oneness in the cosmos through the creation of an ideal order of strings and hidden dimensions in contemporary theoretical physics through string theory.[18] String theory, as I will explain, is based upon mystical, speculative explanations for the nature of the Universe. It postulates an idealized, static reality based upon pre-stated conditions whose dynamics do not interact with the observed Universe. String Theory only sets the parameters for which the physical universe is governed.[19] It represents the creation of a superordinate order that translates down into the Standard Model and General Relativity as an approximation or imitation. Like the translation from the world of essential forms to the imperfect world of observation, the higher world is more real and idealized. This is the antithesis to an

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[17] Peter Woit. *Not Even Wrong* (New York: Basic Books, 2006).

[18] The string theory landscape will be explained later. But for now, let me state that its ramifications are that there are an infinite number of string theories and there is no current way to choose how one set of physical laws is chosen from an infinite multitude of theories.

[19] These standards, such as dimensionality of space, permitted interactions and vibrations of strings as well as the physics of higher-dimensional entities such as branes are all pre-determined before they are utilized in a description of a reality that exists at a more fundamental level than our observed reality. I will discuss this later.

evolutionary approach that underlies the foundations of the Standard Model, and that is a departure from the Standard Model, in which the primary dynamics occur in a transcendent domain that fixes the characteristics of the Standard Model so as to oppose the Popperian Model of Science from which the Standard Model was applied.

It seems to me that String Theorists have insulated themselves from external scrutiny through their self-imposed isolation and intolerance of different perspectives. Their pre-occupation with long, arduous mathematical theories instead of empirical verification seems dogmatic when compared to the revolutionary ideas that eventually seated string theory at the center of contemporary theoretical physics. As a result, it is impossible for even the most proficient theoretician in physics to comprehend what is going on without a strong background in superstring theory.

In order to critique string theory, I will follow the proceeding course. The following chapter will begin with an introduction to the standard model and general relativity, the dual revolutions of the 20th Century that are still in use today. Then, I will explain that in spite of many years of a differentiating cosmology, in which the standard model and general relativity as paradigms operating in separate, distinct spheres, theoretical physicists endeavored to seek out a Grand Unification Theory to explain both paradigms in the form of some more transcendental theory. This undertaking led to a crisis in physics which led to the emergence of string theory in the late 1970s and early 1980s.

I explain the emergence of string theory and its history within the well-established Kuhnian model of scientific paradigms. For reasons that I will show, string theory was established as the paradigm for theoretical physics after 1984. Then, I proceed with a history of string theory, exploring its highlights and its progress to appropriate the spoils of the scientific community. I also give considerable weight to recent discussions in popular and scientific journals that discuss string theory because of the controversy surrounding the long-awaited opening of the LHC later this year. I then suggest that the sociological forces involved in normal science – namely the dogmatism held fast to an unsound paradigm – have permitted string theory to endure as a paradigmatic theory for over thirty-five years in the absence of being subjected to empirical tests. I contend that this is common to what Kuhn describes as normal science.

Finally, I introduce the philosophical mode of thought that string theorists operate in – Platonism. I explain the different roles that Platonic and Aristotelian metaphysics have played in the history of physics and how in periods of experimental breakdown Platonism has emerged as a search for underlying order in the absence of empirical order. Within this framework, I explain how string theory emerged in a period of experimental stagnation as a Platonic attempt to find the oneness in physical laws in the form of a Grand Unification. The transcendental modes of thinking in the idealized realities of hidden strings and mystical branes show a unique example of Platonic thought leaking into the 21st Century. After explaining how Platonic metaphysical thought is at the center of string theory, I show that the rational attempts by string theorists to salvage their theory from contradiction represents a divergence from the Popperian scientific model and is the result of dogmatic endorsement of a thirty-five year search for the most fundamental emanation of what results in the created, dynamic universe that we observe.

Chapter II. Elusive Strings and Mystic Minds

Before I establish string theory's history below, I will try to provide a brief Kuhnian interpretation of major developments in physics leading up to string theory. In the first half of the 20th Century, Einstein's Theory of General Relativity changed the way that physicists approached questions about gravity: General Relativity views the cosmos as an undivided whole, which changes the conventional interpretation as gravity as an attraction between two distinct, separated bodies into an unified interaction of all bodies with the universal gravitational field, which is determined by the degree of curvature of the fabric of space-time.[20] This eliminated the classical Cartesian idea that the world can be broken down into distinct, interacting parts in well-defined locations. One setback came with the establishment of relativity, however – because of Einstein's emphasis on the propagation of signals across space-time, it became impossible to describe extended bodies consistently, because it would imply that signals between the integral parts of the extended body "communicated" with each other at speeds faster than the speed of light (e.g. instantaneously). Therefore, physicists had to assume that particles were point-like (extensionless) for the purpose of general relativity and this created problems for explaining other force fields where an extensionless particle implies an infinite force field.[21] I will explain the relevance of this distinction below.

Around the same time, quantum mechanics was overtaking classical physics. The description of smooth transitions between physical states disappeared, with the concept of discrete transitions (leaps) between states taking its place.[22] Also, physical states and

[20] David Bohm. *Wholeness and the Implicate Order*. (New York: Routledge Classics, 2002) 158.
[21] Ibid, 156-158.
[22] Ibid, 160.

interactions were described by a wave function, which reflected the probability of different actualities emerging from some physical situation, given a statistical ensemble of similar observations. For one isolated observation, no detailed prediction of that observation is possible. The new properties of quantum mechanics introduced a break from the classical notion of well defined particles that interact in ways that can be determined by the properties and causal relationships of each individual particle. [23]

The two revolutions in early 20th Century physics led to many new scientific discoveries. We detected two new force fields in the strong and weak nuclear forces and synthesized quantum descriptions of force fields that eventually led to the standard model. Also, we learned about novel gravitational effects that have been essential in technological advances such as precision corrections to global positioning systems. As a result, the fifty years following the development of quantum theory and general relativity exemplified the Kuhnian period of normal science, where scientists worked by

> extending the knowledge of those facts that the paradigm displays as particularly revealing, by increasing the extent of the match between those facts and the paradigm's predictions, and by further articulation of the paradigm itself.[24]

By the mid 1970s, general relativity had been extended to describe a wide new array of cosmological phenomena and quantum theory had absorbed the three other fundamental forces of the universe into the standard model of particle physics.

Theoretical research in the 1970s, however, led to a new crisis in physics. Although general relativity (for large cosmological events) and the standard model (for

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[23] Bohm, 162-170.
[24] Thomas Kuhn. *The Structure of Scientific Revolutions* (Chicago: The University of Chicago Press, 1996) 24.

particles and fields) had proven their mettle in their respective domains, physicists sought out unification of both theories into a single, unified theory of the cosmos. One outstanding conflict in this effort is that, as I point out above, relativity does not consistently permit extended bodies, forcing particles to be treated as abstracted points.[25] This leads to infinities in standard model calculations for particle interactions.[26] Physicist David Bohm expressed the minority view back in 1980 that,

> The theory of relativity need not just be imposed on quantum theory. It is this imposition of the underlying descriptive order of one theory on another that led to arbitrary features and possible contradictions.[27]

Nevertheless, the majority of physicists would eventually flock to research programs in pursuit of this so-called "imposition" or unification of relativity with the standard model.

It seems to me that this change in research represents a typical Kuhnian crisis, where the disconnect between relativity and the standard model was interpreted by prominent members of the physics community as an "anomaly" and led to the devotion of all of their attention to the creation of a new unified theory. However, as the development of a mathematically consistent unified theory persisted to evade theorists' solution, this problem was transformed into the subject matter of contemporary theoretical physics.[28] As a result, the previous rules of methodology became less stringent and new rules for practice in theoretical physics emerged.[29] There are several tell-tale signs of scientific revolution that emerge prior to this: "the proliferation of competing articulations; the

[25] Bohm 170.
[26] Ibid.
[27] Bohm, 171.
Also, Cf. Bohm, 169-176.
[28] Kuhn, 82-83.
[29] Ibid.

willingness to try anything; the expression of explicit discontent' the recourse to philosophy and to debate over fundamentals."[30]

In the discussion that follows, I will present the rise of string theory as the paradigm that follows the crisis for finding unification of the standard model with general relativity. Its dominance over the theoretical physics field since 1984 suggests that a period of "normal science" has emerged, in which the string theorists have appropriated the spoils of the dominant program for theoretical physics.

String theory originated as a description of strong force interactions. In 1968, Gabreiele Veneziano proposed a mathematical formula that predicted the trajectories for strongly interacting particles scattering off each other.[31] Veneziano's formula predicts the physics of a system with "stringlike" particles extending in one dimension and stretching like rubber bands as they gain and lose energy. Strings, in contrast to point-like particles, require an infinite array of numbers to define their position in space, with three numbers that define each infinitely small point along the string.[32]

The first formulation of string theory proposed several new modifications to our understanding of fundamental physics. Aside from the radical reformulation of fundamental point particles with strings, space was conjectured to span twenty-six dimensions and there had to be tachyon, particles that travel faster than the speed of light. Also, a new type of massless particle was predicted by the theory that could not be explained.[33]

[30] Ibid, 91.
[31] Smolin, 102-103.
[32] Woit, 145.
[33] Smolin, 104-105.

In the years that followed, several mathematical breakthroughs occurred that encouraged the interest of a small community of theorists. The original string theory could only account for bosons[34]; however, in 1970 physicist Pierre Ramond discovered a way to include fermions by adding a mathematical symmetry that “mixes” bosons with fermions in the equations of a string.[35] Ramond’s new mathematical formulation did not predict the existence of tachyons and was consistent with quantum mechanics and special relativity in more physically acceptable ten dimensional space-time.[36] By 1974, Scherk and Schwarz explain that the spin-2 massless particle that was not previously understood carries the characteristics of the graviton, the proposed fundamental particle of a quantum gravitational field.[37] With this accidental discovery, string theory gave the impression of being the theory to finally incorporate a quantum theory of gravity with the fundamental forces of the standard model.

This new theory had unique characteristics to describe all of the fundamental forces and particles. Strings could be open or closed. The newly acquired graviton was supposedly manifest by a closed string, or loop. Bosons can be described by open or closed strings.[38] Charged particles exist at the ends of open strings, while the string can be imagined as the boson that communicates a force between the two particles.[39]

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[34] As I noted in the previous chapter, bosons are particles with integer spin {0,1,2…} like the photon that can transmit forces between charged particles. Fermions are particles with half-integer spin {1/2, 3/2, 5/2 …} like the electron, the proton and the neutron.

[35] This was the first formulation of what became known as supersymmetry, the symmetry that partners each spin half-integer fermion with a “superpartner”, a new integer-spin boson, and vice-versa for bosons. Ibid, 105.

[36] Woit, 145-146.

[37] Woit, 148.

[38] Bosons are force transmitting, integer-spin particles such as the photon and the gluon, the gauge boson for strong force interactions.

[39] Smolin, 106-107

As a result, the picture of physics of the universe was greatly simplified. Forces in string theory were described through the breaking and joining of strings. The manifold constants for forces and particles were replaced by two constants of the string: string tension, which describes the energy per-unit string length and therefore the elementary particle that is created; and the string coupling constant, which expresses the probability of a string breaking into two and communicating a force.[40] And the motion of strings through space is described simply – string motion is restricted so as to minimize the two dimensional area traced out by the string's path.[41] Through what seemed to be a huge reduction in fundamental laws of nature, the dream of string theory became caught up in the pursuit of a beautiful mathematical structure that could unify gravity and the standard model through the vibration and stretching of strings, moving through space-time by a simple law of motion.[42]

The year 1984 is relevant to string theory's history as the point when physicists began to migrate *en masse* to string theory research. In the previous year, prominent theoretical physicist Edward Witten presented a lecture on string theory as a potential unification scheme if only it could be shown that its mathematics was free of infinities, also known as "gauge anomalies." In the summer of 1984, J. Schwarz and M. Green showed that string theory was mathematically free of gauge anomalies and physically consistent with the standard model.[43] This achievement was outstanding because no other unification scheme had previously been able to satisfy the requirements of consistency

[40] Ibid, 108.
[41] When a point-particle moves through space, it traces out a line with its path. A higher dimensional object such as a string actually traces out a two dimensional area with its path.
[42] Ibid, 112-113.
[43] Smolin, 114.

and cancellation of gauge-anomalies. Schwarz and Green's discovery was the starting point for what is now called the first superstring revolution.[44] The adoption of the word "revolution" is based on the fact that physicists were so captivated by the theory that many sacrificed months of research time just to learn string theory's mathematical formulation.[45] Lee Smolin recalls that in the wake of the first superstring revolution, "very quickly there developed an almost cult-like atmosphere."[46] This can be attributed to the rapid conversion of other theoretical research programs into string theory programs and the hostile attitude expressed toward physicists who did not divert their research career to string theory.[47]

The new cadre of string theorists were hopeful that string theory's promise to simplify the twenty constants of the standard model particles and forces into one string constant would be realized soon; however, the next several breakthroughs served to complicate, not simplify, string theory's laws of the universe. Because string theory requires supersymmetry to be consistent with observed physics, it must be defined on ten dimensional space-time, leading some physicists to conjecture that the additional six spatial dimensions are "curled up", too small to probe with any of our contemporary instruments.[48] A 1985 paper by the "Princeton String Quartet"[49] shows that the standard model constants can be derived from the geometric description of the curled up

[44] The name "superstring" was adopted because the majority of viable string theories depend on some form of supersymmetry in their description. Nevertheless, I will use the term "string theory" to stay consistent.
[45] The mathematical tools necessary to work in string theory are highly specialized. If you were a physicist working in another theoretical discipline but wanted to begin working on string theory, you had to devote long hours of training to acquire the skills necessary to solve string theory's problems and would likely have to give up the other research discipline.
[46] Smolin, 116.
[47] Randall, 296-297.
Woit, 151.
[48] Ibid, 118-119.
[49] E. Witten, D. Candelas, G. Horowitz and A. Strominger

dimensions picked from a group of mathematical-topological geometries called Calabi-Yau spaces.[50] More than one hundred thousand distinct Calabi-Yau spaces are known to exist, each giving rise to a unique version of particle physics.[51] This created a crisis for string theorists – strings were supposed to simplify the number of parameters necessary to describe the universe, but in order to remain consistent the Calabi-Yau spaces had to be included as a "compactification" scheme for hiding away the extra dimensions, making it really difficulty to establish a single string theory from the many viable Calabi-Yau geometrical possibilities. In 1986, theorist Andrew Strominger found additional ways to complicate string theory by uncovering even more viable string theory candidates, leading to his regret that "all predictive power seems to have been lost."[52] Few string theorists regarded this as a reality and pushed forward to search for a meta-theory that related all possible geometric schemes for curling up extra dimensions and predicted how an individual string theory that leads to the physics of our universe is chosen from a myriad of possibilities.

By the early 1990s, there were five independent consistent string theories but millions of compactification schemes for curling up the extra dimensions in each. At a string theory conference in 1995, Edward Witten galvanized the community by showing that the five theories are all interrelated by several mathematical dualities between them.[53] Witten introduced T-duality, or topological duality, which states that when one of

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[50] Smolin, 122-123.
[51] Ibid, 123.
This means that there are virtually limitless ways that you can curl up the hidden dimensions, using the many different topological schemes taken from these Calabi-Yau spaces. The caveat is that each way that you curl up the dimensions leads to different values for the fundamental constants of particles, fields and the cosmos, so that each curling up scheme leads to alternate laws of physics, or even alternative universes.
[52] Ibid, 124.
[53] Woit, 154.

the compactified dimensions is a circle, the winding states of one string theory are equivalent to the energy levels in another.[54] There is also an S-duality, or strong-weak duality, which states that in string theory the string coupling constant *g* is large and equal to the inverse of the coupling constant in another string theory, which is small; if true, then the strings in one theory interact more strongly than those in the equivalent theory that interact weakly.[55] The S-duality arises from "emergent properties" that occur in large *g* scenarios where strong interactions cause the emergence of new strings that interact as weakly, as if they are part of the inverse - and weaker - *1/g* theory. It is impossible to determine which strings are fundamental and which are emergent, giving rise to S-duality between strong and weak interacting string theories.[56] In order to relate all five string theories, Witten conjectures the existence of a theory in which there is an eleventh dimension, into which the radius of a circle extends for the conditions that make the duality relations mathematically consistent.[57]

However, supersymmetrical string theory is not a consistent theory in eleven space-time dimensions. The solution proposed by Witten to this problem came in the form of new two-dimensional objects, called branes, which move in eleven dimensional space-time.[58] If one dimension of the theory is assumed to warp into a circle and the brane is wrapped around it, the resulting theory is equivalent to a one-dimensional string

[54]Smolin, 130-131.
Winding number is the number of times a string can wrap around a circle. In two string theories, two circles can be inversely related by their radii ($R_1 = 1/R_2$). Because winding number is equivalent to the inverse of vibration level, the inverse of the number of times a string can wind around radius one is equal to the vibration level, which is also equal to the winding number of a string around radius two.
[55] Ibid, 131.
[56] Smolin 132- 133.
Note that I do not mean strong and weak in terms of the "strong" and "weak" forces. I only mean that the strings are interacting more or less vigorously.
[57] Ibid, 134-135.
[58] Woit, 154-155.

moving through the other ten space-time dimensions and consistent with previous ten-dimensional string theories; furthermore, all of the five string theories can be derived by wrapping branes around the extra dimensions in different ways.[59] Late in 1995, Witten dubbed the largely unknown theory that was proposed through these new geometrical constructions in eleven dimensions M-Theory, and this discovery is recalled as the beginning of a second superstring revolution.

Around the same time, physicist Joseph Polchinski showed that branes are not merely a convention to introduce an additional dimension to string theory without losing consistency. He conjectures that D-branes, a new class of higher dimensional surfaces, must also be included in string theory.[60] These branes are permitted to carry force field charges and open strings are now permitted to end on a brane. Now it is possible to find an even larger number of background geometries where strings live, as determined by both the compactification of extra dimensions and the wrapping configurations of the branes around the many different surfaces and loops created by the extra-dimensional geometry.[61] Polchinski also realized that three dimensional branes are mathematically permitted to stack on one another in such a way as to create the symmetries present in standard model physics, starting up the radical notion that our observed universe might be trapped on a three dimensional surface in a higher dimensional space.[62]

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[59] Smolin 135.
[60] Ibid, 137.
[61] Ibid.
[62] Ibid, 138.

In 1997, Juan Maldacena proposed a new equivalence between string theory and a gauge theory.[63] In what is known as Maldacena's AdS-CFT conjecture, a gauge theory of maximal symmetry exists in four dimensions and is dual, or equivalent, to a five dimensional string theory that exists in anti-de Sitter space.[64] Theorists working on the AdS-CFT conjecture hope that it can be generalized to represent an equivalence between a string theory on five dimensional AdS space and Quantum Chromodynamics, the quantum field theory with no supersymmetry on four dimensional space.[65] According to Lee Smolin, Maldacena's conjecture has only been proven in special limiting cases and the duality is useful only if one of the spaces is explicitly defined, a virtual impossibility.[66]

Although in the two superstring revolutions and much of the work done in the interim observation played a marginal role in the development of string theory, in 1998 a discovery was made that dealt a heavy blow to string theorists' quest to find a single unified theory of physics. Astronomical observations of supernovae in distant galaxies reveal a slowly accelerating expansion of the universe that can only be described as emanating from some dark energy that is distributed homogenously through space.[67] This gradual inflation of the universe can be quantified by a small, but positive, cosmological constant ***c***.[68]

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[63] This is a maximally symmetric theory that represents a quantum field theory with charged, massless particles.
[64] Smolin, 142.
Anti de Sitter space is a maximally symmetric theory of gravity that comes as a solution to Einstein's gravitation equations with negative space-time curvature.
[65] Woit, 157.
[66] Smolin, 142.
[67] Ibid, 150.
[68] Randall, 299.

String theory did not predict dark energy and was not well-suited to accommodate the small positive cosmological constant associated with an inflationary universe. In 2001, Edward Witten admits "I don't know any clear cut way to get de Sitter space (***c*** > 0) from string theory or M-theory."[69] This confounded string theorists, because theory predicts a large negative cosmological constant that would have caused the universe to collapse in its earliest stages or alternatively, a large positive cosmological constant that would propose such a brisk rate of inflation that the universe would have already expanded out to nothing.[70]

A proposition to solve the cosmological constant dilemma came out of an explanation for the stability of extra dimensions. In early 2003, Stanford theorists R. Kallosh, A. Linde, S. Kachru and S. Trivedi discovered that by wrapping a discrete number of branes around the six extra hidden dimensions about each point, the geometry of the extra dimensions was prohibited from fluctuating. The Stanford group realized that by wrapping more branes around the extra dimensions, they could also achieve as small a cosmological constant as they pleased. In addition, by wrapping a different type of brane around the extra dimensions, they showed that the cosmological constant could be made small and positive, in agreement with observed inflationary rates of the universe.[71]

There is a caveat to the discovery made by the Stanford group. The number of string theories that yield a small positive cosmological constant number over 10^{500}.[72] This

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The cosmological constant was first postulated by Einstein as a failed attempt to explain a non-inflationary universe in the face of gravity. Einstein wanted the outward push of a large enough cosmological constant to balance the inward pull of gravity. More recently the cosmological constant has been used to describe universal inflation, where a positive constant implies outward expansion.

[69] Edward Witten, "Quantum Gravity in de Sitter Space," hep-th/0106109. Rpt. in *Smolin*, 154.

[70] Randall, 299.

[71] Smolin, 156-157.

[72] Smolin, 158.

number is so large because there are many ways to curl up the extra dimensions and then wrap branes around them, while still consistent with criteria for a small positive cosmological constant. Many theorists began to accept the notion of a vast landscape of potential string theories. Others, however, deny that such a large number of consistent string theories is even possible.[73] The challenge that faced string theorists was to find a way to do physics with the vast collection of viable theories.

One group of string theorists has adopted the weak Anthropic Principle to explain the way that the landscape of string theories is consistent with our cosmology.[74] These theorists predict a scenario where during the early phase of the universe rapid inflation gave birth to an infinite number of pocket universes, each of which is guided by a string theory from the landscape.[75] According to Leonard Susskind, a prominent theorist and leader of the A.P. movement in string theory, there is no rule for uniquely determining the string theory that governs our physics – we are in a pocket universe in a larger multiverse, which is "filled with diverse environments, most of which are lethal [to human life and for the most part, to a stable Universe]. But the [multiverse] is so big, that statistically speaking, it is very likely that one or more habitable planets exists."[76] Practitioners of the Anthropic argument for explaining our cosmology from the limitless number of cosmological outcomes of the infinite landscape of string theories use an ad-hoc conjecture that our presence in the Universe determines the process by which our

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10^{500} – 1 with 500 zeros following before the decimal point.

[73] Ibid.

[74] The Weak Anthropic Principle is founded upon the following relationship: "Because there are observers in our universe, the universe must possess properties which permit the existence of these observers." Cf. Reinhard Bruer. The Anthropic Principle (Boston, MA: Birkhauser, 1991), 8.

[75] Smolin, 162.

[76] Leonard Susskind. "Final Letter, Smolin vs. Susskind: The Anthropic Principle," http://www.edge.org/3rd_culture/smolin_susskind04/smolin_susskind.html, (17 February 2008), 14.

Universe emerges from an infinite landscape of potential universes. This conjecture has revolutionized the standard by which some contemporary theorists would like to approach physics. In a recent essay, physicist Steven Weinberg asserts

> The larger number of possible values of physical parameters provided by the string landscape, the more string theory legitimates anthropic reasoning as a new basis for physical theories: Any scientists who study nature must live in a part of the landscape where physical parameters take values suitable for the appearance of life and its evolution into scientists.[77]

With no other viable model in string theory, very distinguished scientists have given their endorsement of the anthropic principle to the string landscape:

> 'Those who dislike the anthropic principle are simply in denial'
>
> - Andrei Linde (Stanford University)[78]
>
> 'The possible existence of a huge landscape is a fascinating development in theoretical physics that forces a radical rethinking of many of our assumptions. My gut feeling is that it may well be right.'
>
> - Nima Arkani-Hamed (Harvard University)[79]
>
> 'I think it's quite possible that the landscape is real.'
>
> - Max Tegmark (MIT)[80]

These prominent physicists exude confidence in a radical reformation of what is considered physical and what is philosophical or speculative.

The physicists' conviction of the viability of the string theory landscape has been an enduring asset in the survival of string theory amidst so much uncertainty. What was so compelling about string theory was that it proposed the existence of a consistent and

[77] Steven Weinberg, "Living in the Multiverse," hep-th/0511037. Rpt. in *Smolin*, 168-169.
[78] Smolin, 170.
[79] Ibid.
[80] Ibid.

finite unification scheme after many alternative failed attempts. Therefore, although theorists had been skeptical of extra dimensions and bizarre massless interacting particles before 1984, the confirmation that string theory could be consistent and describe a unified vision of forces was undeniably attractive.[81]

For many physicists, there was elegance in the simplification of the standard model and gravity that influenced their belief in string theory's eventual success as a true picture of the cosmos. Prior to the first superstring revolution, theorist D. Gross remarked to Stanford physicist L. Susskind that "'string theory could not be wrong because its beautiful mathematics could not be accidental.'"[82] J. Schwarz, who discovered that the unknown spin-2 particle in string theory was the graviton, also shows similar optimism: "'String theory was too beautiful a mathematical structure to be completely irrelevant to nature.'"[83] After the second superstring theory, string theorists began to express bizarre intuitions about the mathematics of string theory. Theological speculations have emerged such as Michio Kaku's exclamation that "'the mind of God is music resonating through 11-dimensional hyperspace,'" or a Harvard string theorist who ends his e-mails with the quote: "'Superstring/M-Theory is the language in which God wrote the world.'"[84]

The allure of string theory as a theoretical discipline is clear from the growing number of scientific works on string theory over the years. In the year prior to the first

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[81] Randall, 291.
Smolin, 105.
[82] Leonard Susskind. In L. Hoddeson, L. Brown, M. Riordan, and M. Dresden, eds. *The Rise of the Standard Model* p. 235. Rpt. in *Woit*, 148.
[83] John Schwarz. In H. Newman and T. Ypsilantis, eds. *History of Original Ideas and Basic Discoveries in Particle Physics*. P. 698. Rpt. in *Woit*, 148.
[84] The notion that a physical/mathematical theory is the "language in which God wrote the world," has been cited by physicists often. This dates back to Galileo, who described Nature as a book written in "the language of mathematics."
Michio Kaku. Interview on the *Leonard Lopate Show*, WNYC, January 2, 2004. Rpt. in *Woit*, 211.

superstring revolution (1983), there were sixteen papers published on string theory; in 1984, fifty one papers were published; in 1985, there were 316 and in 1986, 639 published papers on string theory emerged.[85] Since its inception more than thirty years ago, almost forty thousand papers have been written on string theory; in this decade alone, string articles have been published at a rate of 1,500 per year.[86] Over one thousand scientists have worked on some aspect of string theory.[87] One reason for this might be that since 1990, few US research programs hired assistant professors working on approaches to quantum gravity that were not string theory.[88] According to particle cosmologist Lisa Randall, for example, as early as the 1980s at Princeton, the physics department “no longer contained any particle theorists who didn’t work on string theory – a mistake that Princeton has yet to correct.”[89]

The string theorists’ optimism in the mathematics as a path to unification is also evident in their publications, where they argue for their version of a string theory as most probable unification scheme. In the 1985 *Physical Review Letter*s article “Heterotic String,” Gross et al explain having constructed a new type of string theory that reduces to a supersymmetric theory of fields in the limiting condition of low energy.[90] In their theory, the extra dimensions of space are curled up in a specific way to produce more symmetry than previous string theories. The authors speculate that “the heterotic E_8 x E_8 string is perhaps the most promising candidate for a unified field theory.”[91]

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[85] Woit, 159.
[86] Ibid, 162.
[87] Smolin, 177.
[88] Ibid, 263-264.
[89] Randall, 297.
[90] David Gross, et al. “Heterotic String.” *Physical Review Letters* 54.6 (1985): 502-505.
[91] Ibid, 504.

In a 1999 publication of *Review of Modern Physics*, J. Schwarz and N. Seiberg discuss the recent advancements in supersymmetric string theory.[92] Immediately from the introduction, the authors opine about the prospect of unification of the standard model with Einstein's general theory of relativity: "string theory is the only viable attempt to achieve this!"[93] The remainder of the article demonstrates, regardless of how 'viable' string theory is at unifying gravity and quantum field theory, that many mathematical conjectures about the geometry of string theory space had to be made just to unify the several existing string theories. The authors are proud of these mathematical achievements, calling them the basis by which many people judge this theoretical endeavor to be "on the right track."[94] This is clearly a statement of a different standard for scientific evidence, wherein the standard of good scientific methodology is defined by their mathematical achievements of greater unification and transcendence. I will discuss this more in my following chapter on Platonism.

In a 1996 *Physics Today* publication, Edward Witten describes the present understanding of space-time within string theory.[95] He explains the well known notion of how string theory can remove inconsistencies in quantum field interactions by replacing point particles with strings yet is troubled by the elusive supersymmetry upon which many of its notions rest. Witten also argues that through the discovery of dualities before the second superstring revolution, "there is really only one such [string] theory."[96] Then,

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[92] John H. Schwarz, and Nathan Seiberg. "String theory, supersymmetry, unification, and all that." *Reviews of Modern Physics* 71.2 (1999): S112-S120.
[93] Schwarz and Seiberg, S112.
[94] Ibid, S120.
[95] Edward Witten. "Reflections on the Fate of Spacetime." *Physics Today*, 96(4), (1996), 24-30 Rpt. in Callender, Craig and Huggett, Nick, eds., *Physics Meets Philosophy at the Planck Scale* (New York: NY, 2001) 125-137.
[96] Witten in *Callender and Huggett*, 130.

during an argument that string theory has generated powerful models for representing quantum field interactions, he suggests that all of these interactions can be derived more efficiently from a two dimensional interaction paradigm from which Witten makes the radical conclusion that it obviates the need to consider space-time, "except to the extent that one can extract it from a two-dimensional field theory."[97] In the following section in which he explicates his "paradigm," Witten twice calls upon "beauty" in reference to the model and an extension from it.

The optimism amongst string theorists has aroused the criticism of many prominent physicists. Some belong to the earlier generation of particle physicists, who have a paradigm of physics where experiment and theory maintain close kinship. Others are part of a small minority of theoretical physicists, who pursued their own research disciplines outside of string theory. Others yet, such as the mathematical physicist, Sir Roger Penrose, have a unique mathematical perspective to judge string theory. I will begin with the criticisms that Penrose has made.

Penrose's critique of string theory comes from his main complaint that it "gains its support and chooses its directions almost entirely from aesthetic judgments guided by mathematical desiderata."[98] He explains that earlier physical theories that appeared to rest upon mathematical considerations, such as Dirac's discovery of the equation for the electron or Einstein's principle of equivalence, had either observational grounds or some physical basis, while string theory has been entirely driven by mathematics.[99] Another criticism made by Penrose reflects the original claim by string theorists about the

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[97] Ibid, 134.
[98] Penrose, 888.
[99] Ibid, 889-890.

finiteness and consistency of their string theory of quantum gravity. Penrose explains that the early claims of finiteness were very much overstated, which he takes issue with, because of the impact of this statement on the endurance of the theory as a potentially "revolutionary basic framework for future progress in physics."[100] Also, Penrose explains that the current picture of string theory violates the notions of dynamical space as accepted by Einstein's General Theory of Relativity by proposing strings that move on a flat spacetime.[101] Most importantly, Penrose asserts that the claim of finiteness by string theorists has not been rigorously proven, as the finiteness has only been tested up to a second degree approximation and for "ultraviolet (large moment, small distance) divergences."[102] Upon all of his criticisms of string theory, Penrose's most salient is that the mathematical rigor that has helped string theory endure and captivate more scientists is taken for granted by the same theorists who take so much pride in the math.

Many physicists criticize the lack of experimental corroboration in string theory, citing lack of falsifiable theories as well as the lack of new conjectured physical phenomena that could be observed. In the aftermath of the first superstring revolution, Richard Feynman complained that string theorists are more dedicated to proving their theory right than checking it against experiment, exclaiming

> 'I don't like that they don't check their ideas. I don't like that for anything that disagrees with experiment, they cook up an explanation – a fix-up to say 'Well, it still might be true.' … When they write their equation, the equation should decide how many of these [extra dimensions of

[100] Ibid, 893.
[101] Ibid.
[102] Ibid, 909.

> space] get wrapped up, not the desire to agree with experiment.'[103]

To Feynman, there was little exciting about string theory because it seemed to be an ongoing project to obtain our observed cosmology from an initial state that is totally incongruent with reality. One contemporary of Feynman, Sheldon Glashow, also is reluctant to share in the enthusiasm surrounding the first superstring revolution, noting that

> 'superstring physicists have not yet shown that their theory really works. They cannot demonstrate that the standard [model] is a logical outcome of string theory … Why, you may ask, do the string theorists insist that space is nine-dimensional? Simply because string theory doesn't make sense in any other kind of space.'[104]

Glashow's criticism is made against the predictive inability of string theory to anticipate even the most essential components of particle physics – protons and electrons, without even scrutinizing the lack of new experimental predictions anticipated by string theory. For the lack of concrete predictions, Nobel Physicist Gerard t' Hooft calls string theory a hunch, rather than a theory or model because

> 'a theory should come together with instructions on how to deal with it to identify the things one wishes to describe, in our case the elementary particles, and one should, at least in principle, be able to formulate the rules for calculating the properties of these particles, and how to make new predictions for them.'[105]

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[103] Richard Feynmann. Quote in Davies, P.C.W. and Brown, J. eds., *Superstrings: A Theory of Everything* (Cambridge, U.K.: Cambridge Univ. Press, 1988), pp. 194-95 rpt. in *Smolin* 125.
[104] Sheldon Glashow and Ben Bova. *Interactions: A Journey Through the Mind of a Particle Physicist* (New York: Warner Books, 1988), p. 25 rpt. in *Smolin*, 125.
[105] Gerard t' Hooft. *In Search of the Ultimate Building Blocks*. Cambridge University Press, 1997, p. 163 rpt. in *Woit*, 176.

So, without experimental corroboration or any new predictions for physics, these prominent particle physicists cannot share in the optimism of string theory as a new fundamental theory.

Some string theorists have also shared doubts that string theory can really be called a theory or have any predictive capacity. Back in 1983, one year before the first superstring revolution, Edward Witten remarked that, "'what is really unsatisfactory at the moment about the string theory is that it isn't yet a theory.'"[106] The most recent name of a proposed string theory, M-Theory, which purports to be the meta-theory unifying all string theories has been labeled a "misnomer" by theorist T. Banks because, "'it is not a theory, but rather a collection of facts and arguments which suggest the existence of a theory.'"[107] The above arguments point to the lack of a single theory that can be written in a clear, concise way – mathematically or otherwise.

The realization that so many diverse schemes of multidimensional membranes wrapped around many variations in curling up seven extra dimensions has made it virtually impossible to isolate a unique string theory from the potentially infinite other prospects. Against the new fad in string theory to embrace a potential infinite landscape of string theory scenarios, theorist Daniel Friedan expresses pessimism:

> 'String theory failed as a theory of physics because of the existence of a manifold of possible background spacetimes … The long-standing crisis of string theory is its complete failure to explain or predict any long distance physics … String theory cannot give any definite explanations of existing knowledge of the real world and cannot make any definite predictions. The reliability of string theory cannot

[106] Edward Witten. "D = 10 Superstring Theory," in H. A. Weldon, P. Langacker, and P. J. Steinhardt, eds. *Fourth Workship on Grand Unification*. Birkhauser, 1983, p. 395 rpt. in *Woit*, 175.
[107] Tom Banks. *Matrix Theory*, arXiv:hep-th/9710231 rpt. in *Woit*, 176.

> be evaluated, much less established. String theory has no credibility as a candidate theory of physics.'[108]

However, I must stress that this is a minority view and that the persuasive power of such arguments has limited scope.

Articles in popular science journals and general periodicals have given predominantly positive reports on the status of string theory. A 2001 *New York Times* article entitled, "Even Without Evidence, String Theory Gains Influence," reports that although string theory has so far produced only fragments of a complete theory, "'string theorists are already collecting the spoils that ordinarily go to the experimental victors, including federal grants, prestigious awards and tenured faculty positions.'"[109] This uncritical article implies that the theorists will achieve the victory of a complete theory for which their incomplete efforts have already earned them reward and accolade. In a 2005 *Physics Today* book review of *A First Course in String Theory*, Marcelo Gleiser reviews the challenges facing string theory and gives a praising review of the book for making it easier for young theorists to access the mathematical formalism implicit in string theory.[110] Marcelo states that string theory evokes both controversy and awe – controversy for the longstanding lack of experimental evidence and awe from "its elegant mathematical formulation, the symmetries explicitly used, and the promise of a well-behaved quantum theory of gravity that also unifies all fundamental interactions in nature."[111] The deficiency in this account is in the overstatement of mathematical

[108] Daniel Friedan. "A Tentative Theory of Large Distance Physics," arXiv:hep-th/0204131 rpt. in *Smolin*, 194.
[109] James Glanz. "Even Without Evidence, String Theory Gains Influence," *New York Times*, March 13, 2001, rpt. in *Woit*, 227.
[110] Marcelo Gleiser. "A Most Appetizing First Course: *A First Course in String Theory*," *Physics Today* (2005 American Institute of Physics, S-0031-9228-0509-240-9).
[111] Ibid.

elegance and existence of an explicit formula or theory; many non-string theorists could easily interpret this review as suggesting that string theory is simply waiting for the right experiment to confirm or deny a rigorously defined theory. As string theory breaks down into an infinite landscape of solutions, it is not fair to even call string theory a "theory", as I will explore in the following chapter.

In a similar *Physics Today* book review, theorist Juan Maldacena praises *D-Branes*, a mathematical handbook on higher dimensional objects in string theory.[112] According to Maldacena, these new objects led to novel theories such as "new approaches to 'compactifying' string theory so that only the four familiar space-time dimensions are large," and the suggestion that "matter could be localized on a 3[dimensional]-brane that lives in a higher dimensional space."[113] What Maldacena does not explain is that the new methods of compactification eventually lead to the vacuum degeneracy problem that makes choosing a unique string theory impossible and he also avoids mentioning the possibility that a string theory might predict more "compactification" than we observe – maybe all but two dimensions are supposed to curl up in some mathematically consistent string theories.

A rare critical editorial appears in the October 2006 *Physics Today*, titled "Theory in particle physics: Theological speculation versus practical knowledge."[114] Burton Richter, former director of the Stanford Linear Accelerator Center and lifetime experimental particle physicist notes that although many physicists were attracted to string theory as a potential unification of gravity and quantum mechanics, it has fallen

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[112] Juan Maldacena, Review of *D-Branes*, *Physics Today*, (July 2004, American Institute of Physics)
[113] Ibid.
[114] Burton Richter. "Theory in particle physics: Theological speculation versus practical knowledge," *Physics Today* (October 2006, American Institute of Physics) S-0031-9228-0610-210-0.

with the emergence of the landscape, that infinite ensemble of possible string theory solutions. Richter emphasizes that fact that

> No solution that looks like our universe has been found. No correlations have been found such as, for example, if all solutions in the landscape that had a weak coupling anywhere near ours also had a small cosmological constant. What we have is a large number of good people trying to make something more than philosophy out of string theory.[115]

Again, this is a minority view of contemporary theoretical physics.

A May 2007 New York Times article, "A Giant Takes On Physics' Biggest Questions," expresses the severe enthusiasm amongst theoretical physicists for confirmations of supersymmetry, the Higgs boson and string theory at the LHC.[116] The physicists, columnist Dennis Overbye shows, have so deeply invested their careers and relied upon billions of dollars in outside support that failure to detect any new physics could threaten their reputation and the chance of another larger collider ever being commissioned. Overbye states:

> The day it turns on will be a moment of truth for CERN, which has spent 13 years building the collider, and for the world's physicists, who have staked their credibility and their careers, not to mention all those billions of dollars, on the conviction that they are within touching distance of fundamental discoveries about the universe. If they fail to see something new, experts agree, it could be a long time, if ever, before giant particle accelerators are built on Earth again.[117]

Therefore, for physicists it seems virtually impossible for the LHC experiments to not detect anything new. CERN theorist John Ellis says that if the LHC detects no new

[115] Ibid.
[116] Dennis Overbye. "A Giant Takes On Physics' Greates Questions," *New York Times* May 15, 2007. Online: http://www.nytimes.com/2007/05/15/science/15cern.html. 1-10.
[117] Overbye, 2.

particles, then for the last 35 years, "'we theorists have been talking rubbish.'"[118] CERN physicist and deputy spokesperson for the ATLAS, one of the experiments at the LHC, Fabiola Gianotti insists that something new must happen because the new experiments will investigate new energy thresholds where current reigning theories are not applicable; at these higher thresholds, Gianotti lists among possible discoveries the Higgs boson and new space-time dimensions.[119] Supersymmetry is also a potential discovery the LHC physicists hope to make, also carrying great potential as a fix to the dream of explaining all of the forces as the expression of one fundamental force. Although some precise measurements at present-day accelerators should have already yielded information for some of the numerous versions of supersymmetry, the prospect that some other supersymmetric particles could be detected as early as the first day of experiment continues to motivate physicists.[120]

The obvious connection between the discovery of supersymmetry at the LHC and string theory is that supersymmetry emerged from an early version of string theory, and is present in four out of the five main strings theories. There is already skepticism regarding the lack of evidence of supersymmetry detection under current energy thresholds at present-day colliders; if the LHC does not detect supersymmetry, this will all but rule out supersymmetry. But what will this mean for string theory? A December 2007 column in *Physics Today*, titled "String Theory in the age of the Large Hadron Collider," discusses some possible scenarios.[121]

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[118] Ibid.
[119] Ibid, 2-3.
[120] Overbye, 7.
[121] Michael Dine. "String theory in the era of the Large Hadron Collider," *Physics Today* (American Institute of Physics: December 2007) 33-39.

Particle Physicist Michael Dine discusses new string theory physics that could potentially be discovered at the LHC. He affirms that supersymmetry, still without any direct evidence, will be confirmed or rejected by LHC experiments.[122] A theory of large extra dimensions in addition to our four space-time dimensions has been theorized as a solution to the hierarchy problem, but the same precision investigations that should have detected some supersymmetric particles also failed to shed any light on the potential of large extra dimensions.[123] Now, many string theorists have adopted the landscape of a virtual plurality of isolated, metastable universes. Dine explains that the question now posed to string theorists is "Does the landscape provide a solution to the hierarchy problem, with actual predictions for accelerators."[124] Evidently, theorists have identified states in the landscape that suggest the existence of supersymmetry at the LHC; other states have large extra dimensions and others still have none of these aspects, but have a light particle that could be the Higgs boson. String theory will not have any predictive value if it cannot isolate one aspect of new physics over another. Dine admits that the theorists cannot say, "whether the supersymmetric class of states is favored, or the warped class, or states that have a light Higgs simply by accident. We don't yet know the relative numbers of such states, nor do we yet understand the cosmology well enough to determine whether selection effects favor one type or another."[125]

Two substantial assessments of string theory emerged in 2005, in the critical books *Not Even Wrong*, by Peter Woit, and *The Trouble With Physics*, by Lee Smolin. According to the authors, string theory has enjoyed a prominent role in theoretical

[122] Dine, 37.
[123] Dine, 36.
[124] Dine, 38.
[125] Dine, 39.

physics for too long, despite its incomplete status. Although more than 30 years have passed since the inception of superstring theory, no general formulation of a theory has been established. But as a proposal, string theory has drawn the attention of more than one thousand scientists.[126] And since string theory's inception, nearly forty thousand scientific papers have been written on it, at a rate of nearly fifteen hundred per year over the past decade.[127] Many theorists claim that it is too early to assess string theory. On the contrary, Smolin asserts, there is no precedent in the history of science (at least since the 18th Century) in which a proposed major theory endures longer than a decade without either failing or gaining substantial experimental and theoretical support.[128] String theory is undeniably a proposed major theory.

Theorists have overstated the progress of string theory, often claiming that string theory is finite. The theorists are referring to the method by which superstring theory calculations proceed by assigning numbers to hypothetical two-dimensional world-sheets that are swept out in space by moving strings: the sheets are organized topologically according to the number of holes that each one has, leading to a calculation for each hole term. They perform a calculation that returns a number for zero holes, another for one hole and still another for two holes, and so on. Although string theorists conjecture that these terms comprise an infinite sequence for some approximation for some well defined theory, Woit notes that "no one knows what [the theory] is."[129] Worse yet, calculations

[126] Smolin, 177.
[127] Woit, 162.
[128] Smolin, 178.
[129] Woit, 177-178.

have only been done for the first three terms of the hole approximation calculation – for zero, one and two holes.[130]

Some theorists argue that solving the math for this calculation is too difficult. Not true, argues Woit, "few physicists try to (calculate the higher order terms of the hole expansion) [because] they know enough about the answer to know that it will have no supersymmetry breaking and will continue to have the vacuum degeneracy problem, so no predictions will be made."[131] Supersymmetry is not observed in our observed low-energy cosmology so theorists would have to abandon any calculations with terms that express unbroken symmetry in the low-energy limit. Also, the vacuum degeneracy problem comes from the compactification of extra dimensions using Calabi-Yau geometries, because "any Calabi-Yau space of any size and shape is equally good as far as the superstring hole is concerned."[132] It is possible that they will eventually find that all terms of the hole expansion are finite, but there is no certainty that the series of holes is convergent; even if convergence is proven, there will still be an infinite number of consistent theories, each with its own potential to contradict observation with unbroken supersymmetry, degenerate vacuum states and associated massless particles.[133]

Other theorists excuse string theory for our inability to harness sufficient energy to detect string-scale phenomena and the difficulty to extrapolate down to low-energy physics. On the other hand, Smolin argues,

> First, much of the data that string theory was invented to explain already exists in the values of the constants in the standard model … Second, while it is true that strings are

[130] Smolin 280.
[131] Woit 180.
[132] Woit 179.
[133] Woit, 182-183.

> too small to observe directly, previous theories have almost always quickly led to the invention of new experiments – experiments that no one would have thought of doing otherwise.[134]

Woit also argues against citing experimental difficulties, stating that "since there is no real theory, even if a particle accelerator were available that could reach these very high energies, superstring theorists would not be able to make any detailed predictions about what it would see."[135] So, because there is no established theory, string theorists cannot explain the established data that is well described by the standard model and general relativity, nor can they make predictions for experiments at the energy threshold that their proposed theory is supposed to describe. String theory has failed to establish itself by its lack of predictions for both observed phenomena and phenomena yet unseen. The lack of predictive value in string theory, according to Woit, provides "unarguably an example of a theory that can't be falsified (in the Popperian sense)."[136]

As previously noted, there are no basic principles in string theory or even main guiding equations. Smolin notes that no proof exists for a complete formulation of string theory and that "what we know of string theory consists mostly of approximate results and conjectures [concerning] four classes of theories."[137] The theorists argue for the existence of a general formulation of string theory defined by some unknown principles and equations – this unknown theory has many solutions, each giving a consistent string theory on some background space-time. Then, they include new equations to approximate the yet unknown equations of the undetermined theory – these new equations are an

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[134] Smolin 178.
[135] Woit, 180.
[136] Woit, 207.
[137] Smolin, 179

extension of Einstein's general relativity to higher dimensions. And finally, the theorists predict the existence of a string theory for each solution to the approximating equations, regardless of whether they are able to explicitly solve the equations. Smolin explains that the first step is a conjecture because it is unclear whether the theory or equations that would define it exist; step two is a conjecture by association; and, it remains unclear if the approximate equations give sufficient conditions for the existence of a string theory, reducing the entire enterprise to the blind acceptance of an assumption in place of something that needs to be proven.[138] For Woit, string theory is not even a theory: "The problem is that superstring theory is not really a theory, but rather a set of hopes that such a theory exists.[139]

String theory has emerged as an attempt to unify all particles and forces as arising out of the vibrational states of strings on some multi-dimensional space-time. This quest for unification is endemic to the present day scenario in physics wherein, according to Woit, "there are few or no unexplained experimental results, the principle that one should look for simple beautiful theoretical explanations takes on greatly increased importance."[140] It is well established that the standard model and general relativity can explain most physical processes well in their respective domains of applicability, but the string theory enterprise took the initiative to bridge the divide between the two competing theories. The speculative assumption at the root of string theory is that "one should replace the notion of elementary particles with strings or more exotic objects."[141] Although, for example, gravitons emerge naturally from string theory, there is no string

[138] Smolin, 181-182.
[139] Woit, 204.
[140] Woit, 196.
[141] Woit, 208.

theory to date that is formulated as a background-independent theory of space-time in accordance with general relativity, and it cannot be argued yet that general relativity comes as a consequence of string theory.[142] Because of the infinite landscape of consistent string theories, it is impossible to solve the mystery of why the standard model parameters take the unique values that they possess, because so many different string theories could be representative of our standard model cosmology.[143] Smolin finally admits that even if string theory is wrong, it can be relevant for physics if it "*provides evidence for the existence of a more fundamental theory*."[144] Woit, however, is more pessimistic, questioning whether superstring theory should be worthy of even being considered scientific. In his analysis, due to the lack of mathematical rigor and submission to falsifiability, it is not.

I will now briefly summarize the history of string theory. A crisis in physics developed in the 1970s as theorists tried to impose general relativistic principles on the standard model. A series of transcendental theories such as Grand Unification Theories, Supersymmetry and Technicolor were being considered simultaneous with string theory's formulation. By 1984, most of the alternative theories were abandoned and string theory obtained the majority support of the theoretical physics community. This and the movement of many theoretical physicists from various problems to the solution of string theory's problems both represent the acceptance of string theory as the standard paradigm in theoretical physics.

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[142] Smolin, 184.
[143] Smolin, 191.
[144] Smolin 182.

From the first superstring revolution onward, the string theory community worked in a period of normal science. The conventional methodology behind string theory was different from what physicists followed during the development of the standard model because of the extraordinary weight upon the ability to construct a mathematical model that would yield a logically coherent model for physics even while some of its basic tenets were impossible to confirm experimentally. The object of this new normal science was to follow the mathematical foundations of string theory, described by laws of string motion and by the wrapping of extra dimensions, and to find a unique meta-theory that describes the standard model and general relativity as solutions in limiting cases. Obviously, string theorists appropriated the spoils of normal science such as tenured positions, research appointments and government funding.

Many of the original mathematical theories of the first superstring revolution have been proven to be logically inconsistent or contradicted by everyday experience.[145] In order to avoid losing the spoils of paradigmatic standing, string theorists have dogmatically proposed modifications to save string theory from conflicts, with proposals of supersymmetry, many-dimensional branes and duality principles as several occasions of these modifications. These are also natural aspects of normal science, wherein scientists resist the propagation of anomaly for obvious professional reasons as well as faith that their paradigm will be sufficient to describe all of nature.[146]

By the beginning of the 21st Century, cosmological data pointed out an accelerating rate of universal expansion (inflation), which contradicted earlier string theories that proposed a non-accelerating inflationary rate. In order to accommodate this

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[145] See earlier discussions of unbroken supersymmetry, large dimensions and extra forces.
[146] Kuhn, 151-152.

new observation into the paradigm, they had to introduce new phenomena into string theory; namely, branes were now free to wrap around the hidden dimensions in any possible way, with at least 10^{500} ways leading to the positive inflationary acceleration that has been observed. The success of this new theoretical accommodation to string theory came at the price of string theory's uniqueness, whereby each possible way of wrapping branes around strings led to an infinite landscape of string theories, each carrying its own set of physical laws. This was shocking to many string theorists because of its potential to ruin string theory's chances to form any coherent formulation. Currently, many string theorists argue that the Weak Anthropic principle can explain how string theory chooses from its infinite possibilities the conditions for which the laws that permit our existence (and reflection) are possible. This is at best, an *ad hoc* explanation, and at worst, a concession that string theory cannot provide a coherent description of the universe, suggesting that the thirty-five year attempt to incorporate general relativity and the standard model has endured on a purely philosophical basis. Nevertheless, string theorists continue to struggle against another potential Kuhnian crisis, hoping for at least some confirmation of some of string theory's limited statements when the LHC opens in 2009.

In the following chapter, I will discuss the philosophical foundation of string theory that once applied, took on the character of a Kuhnian paradigm and has enjoyed the spoils of normal science as described above. I will show that there is a Platonic transcendental search for mathematical order and unity at the core of string theory.

Chapter III. Metaphysics and Transcendence

In my previous chapters, string theory was introduced, and its development and ascent was traced into the overarching system that predominates the academic endeavors of theoretical physicists. Broadly speaking, however, string theory is actually a generic reference to wide ranging research into the mathematical subtleties for the set of complex and often divergent formulations of supersymmetry, spatial geometries, and higher order dimensions. From these formulations, string theories derive a still hypothetical range of supersymmetrical forces and massless particles, extra dimensions and migrating strings. In its more esoteric and seemingly arcane formulations, string theory postulates alternative universes, a multiverse, from which the three dimensional space occupied by our universe emerged; and the most exotic of all entities, a supercosmic brane, which possesses the creative power to cause the initial conditions and original processes that produced the structure of our universe. At the same time, I described the possible collision course the enterprise of string theory may have with the LHC by year's end, as its foundational predictions are put to high energy tests.

Still, despite the absence of experimental data, or perhaps because no methods of verification for string theory have yet been applied, the string theory masters have had free reign to employ their arcane equations and abstract geometries to apprehend a transcendent order of elusive, one-dimensional strings and primordial branes, moving through any number of extra-dimensional states. The common theme guiding this enterprise is the search for the holy grail of the Grand Unification Theory. Hence, one cannot help but sense the presence of a theological impulse driving this enterprise. To be sure, the extraordinary elegance of the mathematical systems constructed by string theorists is compelling, so much so that these high priests of physics believe that by probing deeper into the abstract symmetries of these systems, they can divine some hidden, though unifying, order to our universe.

With this prelude in mind, I will now suggest that the overwhelming following that string theory has attracted among academic and theoretical physicists has less to do with scientific insight and intuition – constrained as it must be by the observable and knowledge gained through prediction, experimentation and verification – and more to do with *a priori* reasoning coupled with flights of mathematical invention into this brave new transcendent realm. In this regard, string theory has thrived in the absence of scientific rigor, and can be characterized as a regression into the domain of the abstract, symbolic imagination, as the primary means for seeking new explanations for the discontinuities of the physical world. In other words, string theory has ushered in a new metaphysical method for theorizing about particle physics and cosmology. As I argue here, by positing a higher order of reality, this metaphysical approach, though novel in its extraordinary mathematical complexity, actually reflects the re-emergence of Platonic modes of thought in modern physics.

This first brings me to a brief discussion of the role metaphysics has played in the history of physics. Metaphysical notions are useful as foundational assumptions about the natural world, that speculate beyond what can be physically observed or investigated at any given era. Typically, these are *a priori* insights about a more fundamental type of reality that neither outside experience nor experimental methods can perceive. Their utility is pragmatic, and largely determined by the speculative depth of a metaphysical insight in capturing some essence of an unexplained phenomena or undiscovered process.

The presence of the phenomena or process is detected by inference, and indirectly, by observing some unexplained influence or from an unaccountable effect. In this way, the metaphysical insight, by venturing into some unknown process or mechanism operating beyond the real, experiential world, can be useful in guiding further investigation and discovery.

Karl Popper discusses the role of metaphysical notions in the progress of physics in his *Logic of Scientific Discovery*.[147] Popper explains that *a priori* hypotheses yield insight into what can ultimately be tested by empirical data. The primary instrument for interpreting nature is expressed through our, "bold ideas, unjustified anticipations, and speculative thought."[148] And these ideas promote the testing of other ideas by experience, whereby "experiment is planned action in which every step is guided by theory."[149]

As such, metaphysical notions can play a significant role in setting epistemological goals for what we can know, and a standard for how natural laws can be revealed. In fact, metaphysical concepts in physics have facilitated the understanding of such abstract notions of space, time, mass and forces. By establishing the organizing conceptualization about the origin and nature of fundamental reality, metaphysics enabled science to progress in understanding the physical laws that govern the behavior of objects and waves. For example, Gilbert's theory of the "effluvium" helped establish the conception of electric and magnetic forces.[150] Nearly three centuries later, Maxwell

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[147] Karl Popper. *The Logic of Scientific Discovery*. (New York: Harper Torchbook, 1968).
[148] Popper, 280.
[149] Ibid.
[150] The effluvium was a sort of medium through which electricity and magnetism could act across spatial distances. This convention helped develop theories of forces acting between objects separated in space.

conjectured the theory of a “luminiferous Ether” extending throughout space in order to explain the medium through which electromagnetic waves travel.[151]

The history of physics has also presented examples of more generalized metaphysical ideas that set methodological standards for how natural laws can be explored. These standards set such principles as whether what we can observe is essential or an expression of some deeper principle and if our cosmology represents a myriad of fragmented physical laws or is united through some deeper principle. Two competing standards have persisted to emerge as comprehensive metaphysical foundations of physics –Aristotelianism and Platonism.

The Aristotelian metaphysical tradition transmits a logical approach to creating scientific knowledge. This is based upon so-called “first principles” derived from experience, or interaction with nature. For Aristotle, one first principle was that all objects in nature exhibited specific tendencies according to their essences – earth and heavy matter moved downward but fire and light levitated toward the heavens. Aristotle’s theory of locomotion explains that an object’s essential properties determine its motion because, “since some bodies are simple and other compounds of these […] movements must also be simple or some kind of combination, [269[a]1] and simple bodies must have simple movements, compound bodies combined movements.”[152]

According to Aristotle, the nature of how objects act is determined by their essences, and a dynamical relationship between “potentiality” and “actuality”. The

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[151] The classical knowledge of waves understood that there needed to be a medium through which waves could propagate. It was inconceivable that light waves, then, could travel through vacuum space, so physicists of the late 19th Century assumed that there was a medium through which they traveled – the ether.
[152] Aristotle, “On the Heavens,” Rpt in *Space from Zeno to Einstein*. ed. Nick Huggett. (Cambridge, MA: M.I.T. Press, 1999) 61-72.

animals, the plants and the simple bodies (earth, fire, air, water) all present features according to their nature – these each carry within themselves a unique "principle of motion and of stationariness (in respect of place, or of growth and decrease, or by way of alteration)."[153] Aristotle is limiting his discussion to the physical phenomena known during his era – types of motion – but it is reasonable to infer that Aristotle would categorize the physical phenomena we know today according to the properties of each object under investigation. This extension of his idea of a "principle of motion and stationariness" implies that physical laws emerge from those same properties that differentiate one material from another at the observable/empirical level.[154] Aristotle also explains that the nature of things has the potential to change dynamically. This potentiality is inherent in objects and exists independently of the immediate causes of change, also called the actuality, which "cease[s] to exist simultaneously with their effect."[155]

So in the Aristotelian metaphysics, both fundamental and composite things operate according to their fundamental essences. Their natures can be logically determined by first principles based on observation.[156] There is no hidden order or universal law to explain these natures or the changes to the unobscured realm – nature is fragmented with each object acting in accordance with its essential features. The cause of

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[153] Aristotle, *Physics*, Book II Part I Paragraph two Sentence two. http://classics.mit.edu/Aristotle/physics.2.ii.html.
[154] Aristotle, *Physics*, Book II Part I. http://classics.mit.edu/Aristotle/physics.2.ii.html.
[155] Aristotle, *Physics*, Book II Part III Paragraph 12 Sentence three. http://classics.mit.edu/Aristotle/physics.2.ii.html.
[156] Of course, in Aristotle's time this was a very crude rudimentary method. But with contemporary methods, significant insights into nature can be made through advanced detection and observation methods.

change and interaction takes place within and between the essences themselves, which permits dynamic change that takes place on a perceptible outer level.[157]

The aforementioned metaphysical framework stands in contrast to the Platonic metaphysics of "pure forms" and mathematical order. Whereas Aristotelian metaphysics described a dynamical, changing universe, Platonic metaphysics pre-states the states and relationships between all things. In his *Timaeus*, Plato describes how objects in the world of experience come into being through "*that after which the thing coming to be is modeled, and which is its source*."[158] This is the Platonic world of essential forms – those ideal geometric shapes from which all parts of the physical world emerge. Taking example from the Platonic cosmology, the perfect cube represents earth and the perfect pyramid – fire.[159] These essential qualities of the universe originate from pure forms that are rooted in mathematics. Consider the origin of fire through the structure of the pyramid, the "simplest solid figure," which Timaeus explains is derived as follows:

> Its basic unit is the triangle whose hypotenuse is twice the length of its shorter side. If two of these are put together with the hypotenuse as diameter of the resulting figure, and if the process is repeated three times and the diameters and shorter sides of the three figures are made to coincide in the same vertex, the result is a single equilateral triangle composed of six basic units. And if four equilateral triangles are put together, three of their plane angles meet to form a single solid angle [at 180 degrees]: and when four such angles have been formed the result is the simplest solid figure [the pyramid].[160]

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[157] Aristotle, *Physics*, Book II Part III. http://classics.mit.edu/Aristotle/physics.2.ii.html.
[158] Plato. *Timaeus*. Rpt. in *Timaeus and Critias*. tr. Desmond Lee. (New York: Penguin Books, 1977) 70-71.
[159] The cube was assigned to earth because of its stable form derived from isosceles triangles as basic units, and in Plato's cosmology, earth is the singular element that is most stable – it cannot morph into any other element. To fire Plato attributes the pyramid, which contains the least stable faces, and is thus most mobile, penetrating and the lightest. Cf. *Timaeus*, 78-79.
[160] Ibid, 75-76.

And it follows that all of the origins of things in the universe could be known by studying their essential geometric forms – the universe was modeled from these forms. Through this notion, Plato explains the rounded, spherical shape of the universe as suitable to its nature because of its completeness and uniformity as because it is the most suitable shape for containing "all possible figures within itself."[161] Thus, a geometrical order lies at the origin of physical laws, out of which chaos became order.[162]

Plato regards the cosmos as comprising two halves: one half consists of those eternal forms discussed in the *Timaeus* that all elements of the universe are modeled after and the other half consists of the sensory elements that can be perceived through human faculties. In his "Allegory of the Divided Line," Plato relegates these two "ruling powers" to separate spheres, the sphere of opinion and the sphere of knowledge. To summarize, the sphere of knowledge is to the sphere of opinion as an original is to its image as a reflection in water or as an impression in clay.[163] In the sphere of knowledge there is a higher degree of truth. Accordingly, within this "division of the intelligible" there is also a hierarchy of truth. Within the lower subdivision, "the figures given by the former [sphere of opinion] as images; the inquiry can only be hypothetical."[164] The highest division of the intelligible lies in reason, which is attained by the dialectical method,

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[161] Ibid, 45.

[162] A description of ordering, stabilizing effect of rational harmony is deified in the Demiurgos, who ordered the cosmos by introducing "measurable relations, internal and external, among them, to the degree and extent extent that they were capable of proportion and measurement. For at first they stood in no such relations, except by change, nor was there anything that deserved the names [of the elements] which we now use. But [the Demiurgos] reduced them to order, and put together this universe out of them." Cf. *Timaeus*, 96-97.

[163] Plato. *The Republic*. Rpt. in *The Republic and Other Works*. tr Benjamin Jowett. (New York: Dolphin Books, 1960) 202.

[164] Ibid.

> using the hypotheses not as first principles, but only as hypotheses […] as steps and points of departure into a world which is above hypotheses […] by successive steps she descends again without the aid of any sensible object, from ideas, through ideas, and in ideas she ends.[165]

Thus, in his "Divided Line," Plato isolates cultivated understanding twice: once, separating what is intelligible from what can be perceived and again, separating pure ideas from what begins from conventional ideas grounded in perception.[166]

Plato tells us to consult our pure understanding of the essential forms to know the true nature and source of things in our universe because our sensory judgment can only obscure our knowledge about them. We saw the distinction between reason and sensory experience as illustrated in the Divided Line. In the section that follows, the *Allegory of the Cave,* Plato illustrates the condition of man trying to transcend the prison of sensory distractions and rise to the world of essential forms, thus knowing the true origin of things.[167] To briefly summarize, a prisoner – formerly exposed only to shadows moving on the wall of a cave – is allowed to ascend upward into the sun. Plato explains the initial difficulty in dismissing those sensory keys that the prisoner is so accustomed by discussing that, "if he is compelled to look straight at the light [of the sun], will he not have a pain in his eyes which will make him turn away to take refuge in the objects of vision."[168] Finally, the emancipated prisoner will grow accustomed to the enlightened world of pure forms instead of the images on the wall. This represents his transition to true understanding of the origin and nature of things.[169]

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[165] Ibid, 203-204.
[166] Plato. *The Republic*, 202-204.
[167] Plato, *The Republic*. 205-209.
[168] Ibid, 206.
[169] Ibid, 207-209.

The Platonic notion of true scientific knowledge comes from knowledge of a world of unchanging pure forms, from which our observed world of flux and dynamism is assumed to be a kind of reflection: the sensual objects in our cosmos are created as copies of pre-determined ideal shapes. Therefore, the essences of and relationships between objects in our world are *a priori* determined from universal truths about abstract geometric and mathematical forms. The result of this is a metaphysical framework that perceives physical laws as purely mathematical and codifies mathematics as the "mind's eye" through which real physical knowledge of an idealized reality can be investigated.

The development of physics has proceeded according to these two metaphysical frameworks at different times according to the contemporary conditions for doing physics. During periods of intense experimental discovery, physicists can categorize natural laws according to those essential characteristics and dynamical attributes that can be revealed through experimentation and observation. This methodology works in metaphysical modes of thought that could be called rationalist-Aristotelian. On the other hand, when limitations either in experimental precision or theoretical-mathematical understanding have caused the physics enterprise to stagnate, theoreticians sought out deeper, unifying truths in their mathematical equations, which exemplified working in Platonic metaphysical modes.

It seems to me that string theory has emerged with Platonic metaphysical foundations because of the severe breakdown in experiment and in theory during the second half of the twentieth century. After the standard model was established in the early 1970s, there were few open questions left for the physics community. Particle physics was governed by the standard model. Gravitational interactions over large, cosmological scales were subject to Einstein's general relativity. There was only the Higgs boson to be discovered before the standard model would be rendered complete, ushering in a veritable end to theory building. Many conjectured that there would be an "end" to physics as a creative theoretical discipline.[170]

During the period shortly after the standard model was established, theoretical physicists began searching for solutions to the problem of unification of all forces into one primordial force: this began the search for Grand Unified Theories, or GUTs. Some of these theories were discussed earlier in connection to string theory, such as those that invoked supersymmetry. Others invoked symmetries from the mathematical discipline of group theory to try and discover whether the three known forces of the standard model (strong, weak and electromagnetic) could have been unified at some primordial stage in our cosmological history. The experiments constructed to investigate these unification theories failed and the energy thresholds at which the unification of standard model forces were supposed to take place were far beyond the horizon of ever-imaginable particle colliders. Most theorists left these programs after the first superstring revolution.[171]

This brings us to string theory. By the first superstring revolution, string theory established itself as the sole remaining proposal for a grand unification theory of the standard model physics and general relativity.[172] Theorists believed that string theory was certain to succeed in simplifying our current description of the cosmos through the

[170] Smolin, 3-5.
[171] Woit, 95-104
Randall, 233-238 and 257-264.
[172] Remember, the standard model neglects the effects of general relativity because it explains particle interactions over distances and at energies which the gravitational force is too weak to have an impact.

standard model and general relativity by reducing all "fundamental" particles and forces to mere vibrational modes of strings that obey simple laws of motion and energy. The theorists became enamored by the preliminary equations that they had established and interpreted the mathematical beauty of these equations as a sign that their mathematics would lead them to a more fundamental natural law.[173] This began a regression that would lead string theorists toward fundamental ideas about space, time and matter that seemed to become increasingly more detached from what can be experimentally investigated or verified.

String theory is challenging to study because of the high energy thresholds at which its unique tenets might be examined. As with other grand unification theories, the unification threshold is higher than could ever be attained by terrestrial particle accelerators. Also, supersymmetric particles – a requirement for consistent string theories - have certainly not borne witness at present-day colliders, although many physicists are hopeful that the LHC may provide the first glimpse into supersymmetry. Furthermore, the energy threshold theoretically required to probe the string scale itself is higher than even the grand unification thresholds, making it impossible to probe the fundamental strings themselves. I have cited Smolin and Woit for stating that it would not matter if we could probe these energy levels, because string theory does not make any predictions about what would be seen. However, it remains true that string theory is a proposal for a

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[173] Pre-eminent string theorists, such as David Gross and John Schwarz, were motivated by "beautiful mathematics" that could not be "irrelevant to nature," or "accidental." Cf. Woit, 148.
After the superstring revolution, many physicists were convinced that there were no "insuperable obstacles to deriving all of known physics" from string theory and became convinced that string theory was the "physics of the future." Cf. Randall, 296-297.
In more recent accounts, physicists have made more excessive statements about string theory, with at least one according it theological standing as the "language in which God wrote the world." Cf. Woit, 211.

fundamental order that can never be examined at energy scales that could ever be produced within present-day or future energy thresholds.

As I explained in the previous chapter, physicists gravitated to string theory under the premise of finding a potential grand unification of general relativity and the standard model into a single meta-theory of the cosmos. I also mentioned previously that string theory was one of many unification theories that sprouted up in the aftermath of the standard model. Its enduring success alongside failure of other contemporary grand unification theories of its time is a testament to having been defined from the outset as a physical order that cannot be known through observation, and thus cannot be empirically tested as were similar theories.

It is this idealized physical order that string theory defined at the outset that calls attention to Platonic metaphysical origins in string theory. The most revolutionary aspect of string theory is the string itself. Physicists propose to begin with one-dimensional strings moving across hyper-geometrical space with many curled up dimensions and create a meta-theory that is approximately consistent with the standard model and general relativity in low-energy limiting cases. Theorists originally asserted that by replacing point-particles with strings, the laws of physics would be condensed into one fundamental law that explains the expression of our perceived physical laws through the breaking and joining of these fundamental strings. This is strikingly similar to the world of forms, in that the myriad diverse elements of the cosmos that dynamically interact and change are merely the reflection of a higher order reality in which idealized strings move across a 26- 11- or 10-dimensional universe, depending on which version of string theory is in question. The viability of string theory as an enterprise rests upon the claim that the extra-dimensional world of strings can reveal deeper knowledge about the physical world than can be understood by experiment. This world of strings is no less an idealized world of forms than the world outside of Plato's cave.

The string theorists, therefore, are searching for pure forms in their math that are mathematically consistent and have the potential to describe our observed universe as a sort of reflection or limiting case. Through their equations, they seek out a oneness in the universe, envisioning a mathematically theorized Grand Unification Theory as a formal cause.[174] This is a return to the Platonic concept of mathematics as the intermediary between the mind and the universe.

Returning to the Platonic notion of a static reality in the world of forms, string theory pre-states special conditions for a static world of strings. In the world outside the cave, pure forms do not change over time, although their manifestations in the observable world do; likewise, in string theory the fundamental laws of strings, the curling up of hidden dimensions and the warping of branes around the hidden dimensions all represent a fundamental static order that explains the dynamic changes that we perceive in the world of experience of the standard model and general relativity. All string theories seek static solutions in extra dimensional space that may be consistent with observation at a low-energy approximation – so there is no room to suggest whether more or less dimensions are possible, or whether the dimensionality of space could possibly change with time. Therefore, string theorists pre-state static conditions of a higher order (dimensionality of space-time, wrapping of branes, etc.) to be forever unchanging, as the

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[174] I have emphasized this theological aspect in several earlier passages.

fundamental order that describes our perceptibly dynamic ordering and unfolding of physical laws in the cosmos.

Since the second superstring revolution, the *a priori* components of string theory as a grand unified theory have grown to become even more transcendental and speculative. Novel entities such as D-branes have been constructed in order to construct unifying relationships between several string theories. Also, the number of possible exotic configurations in string theory brought about by the number of permissible ways of curling up the extra dimensions increased many-fold because of the addition of the number of ways that branes wrap around the extra dimensions. Therefore, the number of "pure form" parameters that would have to be pre-determined in order to explicitly define a string theory have only increased and led string theorists into transcendental orders of metaphysical speculation.[175]

As the math has undergone an increasing overhaul and revision, a key from the real world has closed all speculation of one unique theory of everything emerging from string theory. Astronomical observations showed that the universe is expanding outward at an accelerating rate; that is, the fabric of space is inflating outward at moderately increasing speeds. As I earlier stated, string theory could explain a static state universe, but then came the turning point in string theory in which a new convention had to be adopted to permit an inflationary universe. This came through the invention of branes. Only by permitting branes to wrap around the extra spatial dimensions could one derive a solution that permits an accelerating inflationary universe. This destroyed the promise of

[175] This is a situation in which string theorists are practicing the old Ptolemaic discipline of adding more spheres to account for inadequacies or incongruities in their theory that is indicative of dogmatic rationalism during Kuhnian periods of "normal science".

uniqueness in string theory, due to the myriad number of ways that describe how the dimensions can be wrapped up, and the number of ways describing how the branes could be wrapped around the dimensions of an inflating universe.[176] So, string theory has become a theory of an infinite landscape of potential theories.

It became evident that there were infinitely many string theories that could be consistent mathematically but lead to an infinite landscape of different scenarios of inflation and physical processes.[177] As a result, the string theory community splintered into two groups: one small constituency continues to pursue the Platonic mathematical harmony in search of a Grand Unification; while the majority has turned toward more ad-hoc explanations of our cosmology by endorsing a weak form of the Anthropic principle. In either case, string theory cannot predict our observed universe as its unique and logical outcome because it cannot at present be codified into a coherent statement of a physical reality, i.e., it cannot as Popper requires be translated into particular observation statements capable of falsifying (or verifying) universal generalizations..

By 2009 the Large Hadron Collider should be fully operational and large swarms of data will have been combed over by some of the world's best physicists. Many novel phenomena may be revealed, but considering the open-endedness of string theory in its present formulation, it is unlikely that the new developments will lead string theory and closer toward refutation, falsification, or even 'verification'. It seems to me that a future refinement of string theory, giving it some sort of "Popperian" refutability would be required before it can progress any further.

[176] There are presently over 10^{500} ways to get a string theory consistent with inflation by different variations of wrapping branes around hidden dimensions.
[177] Many of these theories contained new forces and unbroken supersymmetry that are immediately contradicted by experience.

Popper explains that physics, like all empirical sciences, is built upon a series of theories. He describes theories as, "nets to catch what we call 'the world': to rationalize, to explain, and to master it."[178] The string theory landscape, possessing an infinite number of potential theories of the universe and simultaneously no coherent theory of the universe would disqualify string theory as a theory for Popper. This is because, as a theory, string theory and its landscape of solutions is tautological – because of the infinite potential solutions, any possible theory of the Universe is potentially one of the infinite string theories.[179]

Taken as a whole, string theory is an example of a divergence from the Popperian scientific method. If you even consider those aspects of string theory that are more coherently assembled, there is no effort to subject them to rigorous tests of their consistence or their falsifiability. According to Popper, a theoretical system, either empirical or otherwise, must satisfy some consistency in order to be informative about anything. A self-contradictory system, Popper says, is uninformative because "any conclusion we please can be derived from it. Thus no statement is singled out, either as incompatible or as derivable, since all are derivable."[180] In addition, Popper requires a theoretical system must be refutable; that is, it must be able to differentiate between those basic statements that it prohibits and those that it permits.[181] Popper's criteria for a theory's ability to be refuted lie in the following statement: "a theory is falsifiable if the

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[178] Popper, 59.

[179] A 2005 article about the superstring theorists at Princeton, quotes a prominent theorists saying that "If there is something [beyond string theory], we will call it string theory." Cf. Woit, 227.
Popper notes that there is always a way to avoid falsification in this manner by, "introducing *ad hoc* an auxiliary hypothesis, or by changing *ad hoc* a definition." Cf. Popper, 42.

[180] Popper, 92.

[181] Basic statements are those statements that can serve as the basis for an empirical falsification or as a statement of singular or particular fact. Cf. Popper, 43.

class of potential falsifiers is not empty."[182] String theory, as a theoretical system, does not have any potential falsifiers attributed to it, and, it does not have a consistent basis that expresses what it is, and what it is not. Within the string theory community, the notion that any theory or phenomenon that should arise in the future will still be called string theory because of the limitless scope of what string theory may be. Therefore, it is clearly not compatible with Popper's logical criteria for refutation.

It is apparent that string theorists have not been able to meet the criteria of refutation for their theory. It appears that they have gotten off of the traditional Popperian method and it is still unclear what insights may be called upon in the future for string theory to become a falsifiable theory. Prominent string theorist Joseph Polchinski recently said, "I am sure that all the experimentalists would like to know, 'How do I falsify string theory? How do I make it go away and not come back?' Well you can't. Not yet."[183] Although many string theorists would like to believe that string theory will lead them to a consistent, falsifiable theory of the standard model and general relativity, Popper instructs us to first challenge our bold ideas with sober testing, first logically and then empirically:

> Our method of research is not to defend [theories], in order to prove how right we were. On the contrary, we try to overthrow them. Using all the weapons of our logical, mathematical, and technical armoury, we try to prove that our anticipations were false.[184]

[182] Popper, 86.
[183] Polchinski in *Woit*, 208-209.
[184] Popper, 279.

If the string theory community hopes to develop a falsifiable theory, then the first priority should be to determine what it is, and what it is not. This is the first step toward falsification.

Finally, string theory lacks the inter-subjectivity required of a scientific theory. Popper explains that all "statements which belong to the empirical base of science must also be objective, i.e. inter-subjectively testable [which] implies that, from the statements which are to be tested, other testable statements can be deduced."[185] String theory, which is a statement of proposal to unify general relativity and the standard model, ought to predict new experiments that can reveal new physical phenomena. Instead, string theory has predicted new entities (e.g. strings, branes and hidden dimensions) to explain known phenomena (e.g. standard model physics and general relativity), wherein no new experiments have developed to explore these novel hypothetical entities.

With the first real opportunity to probe the TeV scale, some novel and interesting phenomena will likely be observed. Among its landscape of potential solutions, the supersymmetrical partners to the particles of the standard model are the most likely candidates. On the other hand, such string theory inventions as large extra dimensions, technicolor and grand unifications, are likely beyond the range of LHC to test. Even so, the string theory community has made no concrete statements whatsoever about what the theory predicts will be seen at the LHC. Also, considering the failed precision studies at our present accelerator centers, there is no certainty that any of the exotic symmetric or unification theories or their conjectured particles will be observed.

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[185] Ibid, 47.

This thirty-five year divergence from scientific methodology was supported by the spoils of Kuhnian normal science through accolades and economic advantages, including the professorships and research funding, garnered from adherence to the string theoretical paradigm. It seems to me that string theory's success over this period can be attributed, contrary to Popper, to the dogmatic support that physicists have granted string theory for sociological reasons, which include tenured positions and research grants. String theory does not to live up to Popper's goal of falsifiability, but it is clearly sets guidelines for doing science in a purely Kuhnian way, revealing that Kuhnian and Popperian methodologies are two unique models for doing science, from each of which conclusions can be drawn about the methods employed by string theorists.[186] That is, a new definition of scientific truth has been established through the string theory paradigm, which stands at the center of the notion of a Kuhnian "scientific revolution." Kuhn would argue that string theory is a rationalist approach to unify general relativity and the standard model that exists as a paradigm, both as a proposal and a theory. The lack of experimental confirmation or a consistent theory cannot prohibit string theory from paradigmatic status. In fact, normal science, according to Kuhn, "can be determined in part by the direct inspection of paradigms, a process that […] does not depend upon the formulation of rules […] the existence of a paradigm need not even imply that any full set of rules exists."[187] Within the rules of Kuhnian science, the theoretical physics community has accepted a paradigm, which they identify as string theory, or a proposal for a grand unification of physics, without agreeing upon a full interpretation or

[186] Each paradigm gives particular rules for what a particular scientific discipline is like and defines the methodology for scientific discovery. Cf. Kuhn, 42.
[187] Kuhn, 44.

rationalization of that theory. The nature of "normal science" within that paradigm, is the rational explication, or realization of that theory as mathematically coherent. The "scientific truth" in a purely Kuhnian essence, is that general relativity and the standard model are unified through string theory. Then, the "normal science" lies in the rationalization of mathematics to find a logically consistent description of said truth.[188]

This presentation of Kuhn and Popper represents two distinct versions of how science is conducted. Ultimately, string theory operates as an example of Kuhnian normal science. This model rests upon the conviction that a synthesis between general relativity and the standard model exists and can someday be logically described by a still amorphous proposal for a theory of strings.[189] But this is inevitable, for were string theory to have been grounded in the Popperian falsifiability, it could not have passed logical inspection through the logic of refutationism. The bold ideas that led to string theory are incontestably captivating, and in the Popperian method, science always begins with bold ideas.[190] However, Popper would warn us that the subjective experiences of conviction or faith, which present themselves in normal science in the form of "scientific truths" and especially in string theory are the "idols of certainty," that "bar the way of scientific advance."[191] Popper champions the heroic vision of scientific method in spite of the lack of absolute *episteme* in the following manner:

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[188] This is representative of Kuhn's analogy of normal science as puzzle solving, wherein the puzzle solving is solving the equations that determine a unification between general relativity and the standard model. It is as if string theory, as the paradigm, is also the puzzle proposed to its scientists, the theoretical physicists, to solve. Cf. Kuhn, 35-42.

[189] By amorphous, I mean completely ambiguous. String theory, by and through its current representation in the landscape principle, lacks a consistent formulation as a theory. It predicts nothing and everything simultaneously; therefore, it is amorphous.

[190] Popper, 279-280.

[191] Ibid, 280-281.

> Science never pursues the illusory aim of making its answers final, or even probable. Its advance is, rather, towards an infinite yet attainable aim: that of ever discovering new, deeper, and more general problems, and of subjecting our ever tentative answers to ever renewed and ever more rigorous tests.[192]

Thus, in Popper we have an alternative method to scientific discovery in which bold, imaginative conjectures like string theory are always tempered by critical testing rather than cultivating them into dogmatically upheld paradigms, in the Kuhnian sense. This speculative motivation led to the abandonment of the Popperian scientific method that motivated the physics of the standard model and general relativity and took hold of a new version of scientific truth through the establishment of a new Kuhnian paradigm. In the final analysis, string theory originated from a search for mathematical harmony in the equations of the standard model and general relativity, and the majority of the string theory community continues to work according to these Platonic modes of thought.

[192] Ibid, 281.

Epilogue

The absence of predictive value and experimental verification is both what allowed this enterprise of string theory to consume the efforts of the most gifted mathematical physicists for over thirty-five years, and what may ultimately doom that enterprise as an artifact of 20th Century Science in the near future. This can be explained by the absence of experimental protocols or a falsifiable theory, which enabled string theorists to construct grand mathematical frameworks to apprehend an ultimate reality beyond the testable limits of what can be observed or even perceived. By adopting what are, at their core, Platonic methods of describing the universe in terms of mathematical order and geometric origins, the string theorists gave expression to transcendental habits of mind. In their search for a unifying oneness in the form of a new grand unification theory, this effort appears more characteristic of theology, than a scientific endeavor.

Bibliography

Aristotle. *On the Heavens*. Rpt in *Space from Zeno to Einstein*. ed. Nick Huggett. (Cambridge, MA: M.I.T. Press, 1999) 61-72.

Aristotle, *Physics*, Book II Part I. http://classics.mit.edu/Aristotle/physics.2.ii.html.

Banks, Tom. *Matrix Theory*, arXiv:hep-th/9710231 rpt. in *Woit*, 176.

Bohm, David. *Wholeness and the Implicate Order*. (New York: Routledge Classics, 2002).

Bruer, Reinhard. *The Anthropic Principle*. (Boston, MA: Birkhauser, 1991).

Callender, Craig and Huggett, Nick, eds., *Physics Meets Philosophy at the Planck Scale* (New York: NY, 2001)

Collins, Graham P. "Large Hadron Collider: The Discovery Machine" *Scientific American* (February 2008): 39-45.

Dine, Michael. "String theory in the era of the Large Hadron Collider," *Physics Today* (American Institute of Physics: December 2007) 33-39.

Feynman, Richard. Quote in Davies, P.C.W. and Brown, J. eds., *Superstrings: A Theory of Everything* (Cambridge, U.K.: Cambridge Univ. Press, 1988), pp. 194-95 rpt. in *Smolin*, 125.

Friedan, Daniel. "A Tentative Theory of Large Distance Physics," arXiv:hep-th/0204131 rpt. in *Smolin*, 194.

Glanz, James. "Even Without Evidence, String Theory Gains Influence," *New York Times*, March 13, 2001, rpt. in *Woit*, 227.

Gleiser, Marcelo. "A Most Appetizing First Course: *A First Course in String Theory*," *Physics Today* (2005 American Institute of Physics, S-0031-9228-0509-240-9).

Glashow, Sheldon and Bova, Ben. *Interactions: A Journey Through the Mind of a Particle Physicist* (New York: Warner Books, 1988), p. 25 rpt. in *Smolin*, 125.

Gross, David. et al. "Heterotic String." *Physical Review Letters* 54.6 (1985): 502-505.

Huggett, Nick. *Space from Zeno to Einstein*. (Cambridge, MA: M.I.T. Press, 1999).

Kaku, Michio. Interview on the *Leonard Lopate Show*, WNYC, January 2, 2004. Rpt. in *Woit*, 211.

Kane, Gordon. *Supersymmetry.* (New York: Da Capo Books, 2000).

Kuhn, Thomas. *The Structure of Scientific Revolutions.* (Chicago: The University of Chicago Press, 1996).

Maldacena, Juan. Review of *D-Branes*, *Physics Today*, (July 2004, American Institute of Physics).

Overbye, Dennis. “A Giant Takes On Physics’ Greates Questions,” *New York Times* May 15, 2007. Online: http://www.nytimes.com/2007/05/15/science/15cern.html. 1-10.

Penrose, Roger. *The Road to Reality*. (New York: Alfred A. Knopf, 2004).

Plato. *Timaeus*. Rpt. in *Timaeus and Critias*. tr. Desmond Lee. (New York: Penguin Books, 1977).

Plato. *The Republic*. Rpt. in *The Republic and Other Works*. tr Benjamin Jowett. (New York: Dolphin Books, 1960).

Popper, Karl. *The Logic of Scientific Discovery*. (New York: Harper Torchbook, 1968).

Randall, Lisa. *Warped Passages.* (New York: HarperCollins Publishers, 2005).

Richter, Burton. “Theory in particle physics: Theological speculation versus practical knowledge,” *Physics Today* (October 2006, American Institute of Physics) S-0031-9228-0610-210-0.

Schwarz, John. In H. Newman and T. Ypsilantis, eds. *History of Original Ideas and Basic Discoveries in Particle Physics*. p. 698. Rpt. in *Woit*, 148.

Schwarz, John H. and Seiberg, Nathan. “String theory, supersymmetry, unification, and all that.” *Reviews of Modern Physics* 71.2 (1999): S112-S120.

Smolin, Lee. *The Trouble with Physics.* (New York: Houghton Mifflin Company, 2006).

Susskind, Leonard. “Final Letter, Smolin vs. Susskind: The Anthropic Principle.” http://www.edge.org/3rd_culture/smolin_susskind04/smolin_susskind.html. (17 February 2008).

Susskind, Leonard. In L. Hoddeson, L. Brown, M. Riordan, and M. Dresden, eds. *The Rise of the Standard Model* p. 235. Rpt. in *Woit*, 148.

t' Hooft, Gerard. *In Search of the Ultimate Building Blocks*. Cambridge University Press, 1997, p. 163 rpt. in *Woit*, 176.

Weinberg, Steven. “Living in the Multiverse.” hep-th/0511037. Rpt. in *Smolin*, 168-169.

Witten, E. “D = 10 Superstring Theory,” in H. A. Weldon, P. Langacker, and P. J. Steinhardt, eds. *Fourth Workship on Grand Unification*. Birkhauser, 1983, p. 395 rpt. in *Woit*, 175.

Witten, Edward. “Quantum Gravity in de Sitter Space,” hep-th/0106109. Rpt. in *Smolin*, 154.

Witten, Edward. “Reflections on the Fate of Spacetime.” *Physics Today*, 96(4), (1996), 24-30 Rpt. in Callender, Craig and Huggett, Nick, eds., *Physics Meets Philosophy at the Planck Scale* (New York: NY, 2001) 125-137.

Woit, Peter. *Not Even Wrong.* (New York: Basic Books, 2006).

When drafting Frames of Mind I was writing as a psychologist, and to this day that remains my primary scholarly identification. Yet, given the mission of the van Leer Foundation and my affiliation with the Har- vard Graduate School of Education, it was clear to me that I needed to say something about the educational implications of MI theory. And so, I xii Multiple Intelligences: The First Thirty Years conducted background research about schools and about education, more broadly defined; in the concluding chapters I speculated about some ed- ucational implications of the theory. This nod towar Regular physics is unsatisfactory in that it fails to take into consideration phenomena relating to mind and meaning, whereas on the other side of the cultural divide such constructs have been studied in detail. This paper discusses a possible synthesis of the two perspectives. Crucial is the way systems realising mental function can develop step by step on the basis of the scaffolding mechanisms of Hoffmeyer, in a way that can be clarified by consideration of the phenomenon of language. â€¢ For the Platonists. One crucial consequence of the Platonic position is that it views mathematics as a project akin to physics, Platonic mathematicians beingâ€"as physicists cer-tainly areâ€"describers or possibly predictorsâ€"not, of course, of the physical world, but of some other more noetic entity. Mathematicsâ€"from the Platonic perspectiveâ€"aims, among other things, to come up with the most faithful description of that entity. 3.3. More Implication of No-Boundary Emergence in Modern Physics. 4. emergence in concept world. 4.1. Progressive Scientific Research Programme.Â In modern cosmology, the Big Bang theory indicates the existence of singularity wherein the equations of gravitational field cannot be defined at some points in the history of the universe, pointing to General Relativity's failure in explaining the beginning of our universe. As a result, Big Bang theory posits that it cannot predict anything in our universe, which means that an arbitrary initial state resulted in an arbitrary current state. As we know, in Quantum Theory, there is a principle that everything will happen if not absolutely forbidden.