CHIMERA OF THE COSMOS

By

Eric Nelson Hatleback

Bachelor of Science, University of Wisconsin – Oshkosh, 2003

Master of Arts, Western Michigan University, 2005

Submitted to the Graduate Faculty of the

Kenneth P. Dietrich School of Arts and Sciences

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2014

UNIVERSITY OF PITTSBURGH

DEPARTMENT OF HISTORY & PHILOSOPHY OF SCIENCE

This dissertation was presented

by

Eric Nelson Hatleback

It was defended on

July 31, 2014

and approved by

John D. Norton, Professor, Department of History & Philosophy of Science

George Gale, Professor, Department of Philosophy (University of Missouri – Kansas City)

Allen Janis, Professor Emeritus, Department of Physics & Astronomy

Paolo Palmieri, Associate Professor, Department of History & Philosophy of Science

James Woodward, Distinguished Professor, Department of History & Philosophy of Science

Dissertation Advisor: John D. Norton, Professor, Department of History & Philosophy of Science

CHIMERA OF THE COSMOS

Eric Nelson Hatleback, PhD

University of Pittsburgh, 2014

Multiverse cosmology exhibits unique epistemic problems because it posits the existence of universes inaccessible from our own. Since empirical investigation is not possible, philosophical investigation takes a prominent role. The inaccessibility of the other universes causes argumentation for the multiverse hypothesis to be wholly dependent upon typicality assumptions that relate our observed universe to the unobserved universes. The necessary reliance on typicality assumptions results in the Multiverse Circularity Problem: the multiverse hypothesis is justified only through invoking typicality assumptions, but typicality assumptions are justified only through invoking the multiverse hypothesis. The unavoidability of the circularity is established through argumentation for each of the two conjuncts that comprise it.

Historical investigation proves the first conjunct of the Multiverse Circularity Problem. Detailed study of the now-neglected tradition of multiverse thought shows that philosophers and scientists have postulated the multiverse hypothesis with regularity, under different names, since antiquity. The corpus of argumentation for the existence of the multiverse breaks cleanly into three distinct argument schemas: implication from physics, induction, and explanation. Each of the three argument schemas is shown to be fully reliant upon unsupported typicality assumptions. This demonstrates that the multiverse hypothesis is justified only through invoking typicality assumptions.

Philosophical assessment of cosmological induction establishes the second conjunct of the Multiverse Circularity Problem. Independent justification for typicality assumptions is not forthcoming. The obvious candidate, enumerative induction, fails: Hume's attack against inference through time is extended to inference through space. This move undercuts external justification for typicality assumptions, such as the Cosmological Principle, which cosmologists implement to justify induction. Removing the legitimacy of enumerative induction shows that typicality assumptions are justified only through invoking the multiverse hypothesis, thereby establishing the Multiverse Circularity Problem.

Table of Contents

List of Figures

Preface

The influences that shape a work of this magnitude are difficult to contextualize. To identify when and why my interest developed in thinking carefully about the possibility of other worlds feels impossible; no doubt it has been present as long as I can remember. To thank those who have contributed influence along the way—so many in a small space like this—feels both daunting and doomed to failure. Those who know me best know that none are forgotten: I could never hope to "order" those who are important to me. So, just as the order in which I present the following cannot be anything but arbitrary, so, too, can mention here be nothing other than arbitrary. None are forgotten.

To begin arbitrarily, my initial formal philosophical development began at the University of Wisconsin – Oshkosh. There, Laurence Carlin and Marshall Missner contributed immensely to my early development both as a philosopher and as a teacher. At Western Michigan University, Tim McGrew took me immediately under his tutelage and taught me the importance of precision and polish for my professional development. At the University of Pittsburgh, John Norton and Paolo Palmieri have been exceedingly important mentors for me. My interest in the history of science will forever be rooted in my time at the HPS Lab recreating experiments with Paolo, and it is thanks to John that I will never shy away from addressing the question at hand directly, rather than resorting merely to safe or acceptable cosmetic "solutions." Regarding this project in particular, I am immensely grateful to John and Paolo, as well as to George Gale, Al Janis, and Jim Woodward. Together, they were the committee that guided me in creating this work; their contributions to my scholarly development are invaluable.

No endeavors are worthwhile without companions with which to undertake them. This particular endeavor would not be what it is—and even may not have occurred—if it were not for the friends that I have made along the way. Truly, there are too many to mention. So, arbitrarily, I will note that my time in Kalamazoo was spent mostly with Quentin Gee, and likewise my time in Pittsburgh has been spent mostly with Elay Shech. And my time in life overall has been spent

mostly with Sean Fitzgerald. Those three lifelong friends have been, and will be, along for many other endeavors beyond this one.

In a separate class of influence altogether is my family. Here is the one place where arbitrariness does not apply: any thanks I could offer to any set of people would include my family. I cannot overstate the importance of the support I have received over the years from my parents and my brother. As is only possible with family, they always have known when to ask questions and when not to ask questions. I am grateful to my grandparents, as well, for offering unconditional support. Working early in the morning or late into the night has never been lonely, thanks to the companionship of Mage, Magellan, and Shiva, just as Rikki always was there when I was younger. Finally, I cannot adequately put into words the support I have received from Allison Stuart, the love of my life. Needless to say, it transcends anything I would write in the preface to any document, so I will not struggle to try to say more than that.

0
Prologue

In 1974, Brandon Carter published what is widely credited to be the first account of "anthropic reasoning." There, Carter outlined his previously ruminating thoughts concerning the Weak Anthropic Principle (WAP) and the Strong Anthropic Principle (SAP). Thus began a tumultuous (and still on-going) episode for physicists and philosophers of science grappling with the implications of observational selection effects with respect to the existence of observers.

Formulations of the WAP have since contributed heavily to the multiverse literature, especially concerning explanation of the apparently fine-tuned nature of our universe. Multiverse theories, inherently unverifiable, seem to gain support when reasoning along anthropic lines: a multitude (or perhaps even a plenitude) of actually existing universes helps ease the surprise that our universe is compatible with observers. Thus, in a very important sense, Carter's introduction of WAP into reasoning about cosmology has shaped the trajectory of the philosophy of the discipline.

Carter's foray into anthropic reasoning issued in part from an exchange between R.H. Dicke and Paul Dirac that occurred in 1961 in the pages of *Nature*. There, Dirac seeks to explain a coincidence that appears to be present within the dimensionless fundamental cosmological constants: many lie at a magnitude $\sim 10^{40}$. This prompted Dirac to speculate that those dimensionless quantities involving T, the Hubble age of the universe, must correspondingly include constants whose values change as time proceeds to maintain the dimensionless relationship to 10^{40}. Dicke contends that Dirac's postulate is false. Dicke's argument involves demonstrating that the values of such constants need not vary with time because those involving T are coincidentally observed to lie near the magnitude 10^{40} owing to the fact that observation can occur only during a restricted segment of the continuum of values taken on by T. Thus, for example, the value of the dimensionless constant

$$T \frac{m_p C}{h} \sim 10^{42},$$

with m_p representing the mass of an elementary particle, need not indicate that m_p, c, or h vary as T increases in order to maintain the close ties to 10^{40} exhibited by the dimensionless combination. Rather, contends Dicke, the dimensionless combination happens to lie close to 10^{40} because it is not possible to observe T to be outside of the narrow segment within which it now lies (despite the fact that it has been and likely will be once again outside this segment).

Carter harnessed this line of reasoning and revised it into a general principle, the WAP, whereby "what we can expect to observe must be restricted by the conditions necessary for our presence as observers."[1] The years since have seen the Dicke-Dirac-Carter exchange credited for introducing anthropic reasoning into the philosophy of cosmology literature. A blueprint for that type of reasoning can be distilled from the components just outlined. The WAP, at its heart, is a very specific explanatory principle of reasoning involving observational selection effects of a very specific kind. Since it has become customary for writers who discuss the WAP to do so via simplified analogies, it is fitting to break the WAP into its components within the setting of these well-known examples.

Though Arthur Eddington did not write with the WAP in mind—his *The Philosophy of Physical Science* was written in 1939, well before Carter's work—he investigates observational selection effects by means of an analogy that would be oft-returned to in the wake of the WAP's emergence. That analogy involves catching fish with a net of particular size. Eddington intends for the analogy to display the observational selection effect inherent in obtaining scientific knowledge.[2] An ichthyologist who utilizes a net with two-inch holes to capture his catch might conclude that "no sea-creature is less than two inches long."[3] Eddington operates under parameters whereby scientific knowledge is represented by what is caught in the net and the net itself represents our observational abilities (senses, tools, and measurement devices, for instance). The ichthyologist, of course, represents a scientist trying to gather knowledge. Eddington's example very clearly demonstrates an observational selection effect: the ichthyologist (scientist) can only capture sea-creatures (scientific knowledge) that his net (observational ability) is capable of capturing.

---

[1] Carter (1974), p. 291.
[2] Eddington (1939), p. 16-21.
[3] Eddington (1939), p. 16.

After Carter introduced the WAP, many writers returned to (and modified) Eddington's analogy in attempts to explicate the implications of reasoning in accordance with WAP. John Leslie, for example, carries Eddington's analogy into the realm of anthropic reasoning in what he calls the Fishing Story.[4] Leslie's aim is to demonstrate how the analogy introduced by Eddington can be implemented for the purpose of explanation with respect to the fish in the lake. He writes, concerning the just-caught fish of 23.2576 inches and the realization that the apparatus can only catch fish of exactly this length (to within a ten-thousandth of an inch):

> Competing theories spring to mind: the first, that there are millions of differently lengthed fish in the lake, your apparatus having in the end found one fitting its requirements; and the second, that there is just the one fish, created by someone wishing to give you a fish supper. Either explanation will serve; and so for that matter will the explanation that the well-wisher created so many fish of different lengths that there would be sure to be one which you could catch. (God and Multiple Worlds are far from being flatly incompatible.) In contrast, *that the one and only fish in the lake just happened to be of exactly the right length* is a suggestion to be rejected at once. Similarly with the suggestion *that the lake contains many fish, all of a length which just happens to be the right one...*There are subsidiary morals too. Thus, notice how you cannot account for catching your fish by considering many *merely possible* fish, remarking that only fish of just about exactly 23.2576 inches could be caught, and then declaring that this would sufficiently explain the affair even if yours had been the only fish in the lake. What you instead need is either a benevolent fish-creating person or else a lake with many *actual* fish of varied lengths. The fish, really existing fish, of lengths which cannot be caught, help to render unmysterious the catching of the fish which can be.[5]

There are two crucially important elements to take away from Leslie's extension of Eddington's example. The first is that Leslie presents this case with the intention of reaching beyond merely the observational selection effect that it demonstrates. Leslie customizes it (by sharpening the precision of the fishing apparatus) in order to display the manner in which one might draw conclusions about the full set of objects from which one draws a sample. He maintains that the catching of a fish with such a specific length (given the apparatus in use) can be *explained* by recognizing that there are (uncatchable) fish of other lengths in the water (or that a benevolent fish-creator placed the fish there to be caught).

Secondly, it is of paramount importance to recognize that, like Eddington, Leslie uses the example as an analogy. Leslie intends for his Fishing Story to strike a resemblance in reasoning

[4] Leslie presents his Fishing Story in several places, among them Leslie (1988), p. 270, and Leslie (1989), pp. 9-10.
[5] Leslie (1989), pp. 9-10. Emphasis and parenthetical statement in original.

between the fishing case and the case of implementing the WAP in the multiverse context: the fish in the lake represent the miniverses in the multiverse and the length of a fish represents the values of the fundamental constants within a miniverse. Yet there is, of course, a difference between the Fishing Story and the multiverse case. The difference is revealed by noting that nowhere in the Fishing Story is there mention of the fisherman's existence being tied to the length of the fish that he catches. (In the multiverse case, however, the existence of the observer within a miniverse is very much tied to the values of the fundamental constants in place in that miniverse.) This means that there is a piece of the WAP that the analogy presented in the Fishing Story does not capture. That piece is readily identifiable as the portion of Carter's WAP that references "the conditions necessary for our presence as observers." The extension from Leslie's Fishing Story to the multiverse case thereby occurs at this very point: it involves porting over the reasoning in use in the fishing case to the case that deals with the conditions necessary for the existence of the observer in the multiverse. In essence, the observational selection effect is shifted from addressing which objects can be observed to addressing the more fundamental query involving which settings permit observation at all. It is that specific bit—the bit that involves the conditions necessary for the existence of the observer—that separates reasoning in accordance with the WAP from the reasoning in place in the fishing examples of Eddington and Leslie. If there were no difference between the fishing case and the multiverse case, then the WAP itself would be the principle of reasoning at work in the Fishing Story. Instead, Leslie's extension of Eddington's fishing analogy points to an important component of Carter's WAP and its implementation.

Thus we see how reasoning in accordance with the WAP stands out from reasoning in accordance with run-of-the-mill observational selection effects in two ways. The first is that the selection effect in the WAP is employed for the purpose of explanation. The second is that it is applied to the setting in which the observer is (or could be) found rather than to the objects being observed by the observer. These two extensions to an observational selection effect are the pieces that fell into place in Carter's christening of the WAP. All told, then, WAP is comprised of three facets:

WAP$_1$: An observational selection effect,

WAP$_2$: Inclusion of explanatory import, and

WAP$_3$: Application of the selection effect to observer-compatible settings.

A complete analysis of Carter's introduction of the WAP thereby finds it broken into three distinct components: *what we can expect to observe* (WAP_2) *must be restricted* (WAP_1) *by the conditions necessary for our presence as observers* (WAP_3).[6] A return to the literature with which Carter worked fully demonstrates this interplay.

The first element among those comprising WAP is the necessary inclusion of an observational selection effect. For Dicke, this took the form of the simple realization that despite the fact that T ranged over a continuum of values of which the upper bound (and perhaps also the lower bound) cannot be discerned, only a small subset of those values are capable of being observed.[7] This satisfies the basic requirement of WAP_1: the value of T always will be observed to lie within the restricted segment of its potential values. The observed values of T thereby come packaged with an observational selection effect, and this will impact perceived coincidences of dimensionless fundamental cosmological constants that include T as a building block. Carter includes the observational selection effect in the middle of his formulation of WAP, which concerns the restriction necessarily imposed upon the possible observations made by observers. This basic observational selection effect—restricting the observations that can be made—is the WAP_1 component of the WAP. (The factors that collectively *generate* the restriction on what is capable of being observed are of the utmost interest in any case where an observational selection effect is at work, of course. But those factors in this case relate directly to WAP_3, so discussion of them will be momentarily postponed while WAP_2 is addressed.)

The second essential component of Carter's WAP is unearthed by noting that its formulation makes the WAP conducive to implementation for the purposes of explanation, since it deals with expectation and, *ipso facto*, the mitigation of surprise. Dicke's retort to Dirac, which factored heavily in Carter's creation of WAP, displays the explanatory element of anthropic reasoning that Carter includes in the WAP. Dicke uses the observational selection effect inherent in the observed value of T to *explain* the apparent coincidence of the values of the dimensionless constants. The first portion of Carter's formulation of the WAP involves expectation, which should be construed

[6] Note that this formulation connects expectation (or lack of surprise) to explanation, as Carter intends, for the WAP_2 component. Of course, not all theorists agree that this properly captures what is necessary for a scientific explanation, and those theorists typically disagree with the notion that WAP has explanatory import. Nevertheless, for the time being, we will proceed, since those whose work is currently under consideration (Carter especially) take explanation to be of this sort. See below for details.

[7] The "capable" piece of this statement is important, since dealing with what merely *is* (or *has been* or *will be*) observed is much different from dealing with what *it is possible* to observe. It is the *capability* of observation that identifies an observational selection effect.

as imparting the element of explanation to the WAP that Dicke invoked in objecting to Dirac's postulate. As was the case with the observational selection effect, Carter generalizes Dicke's line of reasoning; Carter identifies the subject matter of the WAP as that which one can *expect* to observe. So WAP's second component speaks of explanation. Carter explicitly acknowledges Dicke's employment of the WAP for explanation, saying that "a prediction based only on the *weak* anthropic principle (as used by Dicke) can amount to a complete physical explanation."[8] This involvement of explanation comprises the WAP_2 component.

Carter's inclusion of explanatory import as part of the WAP permits the reasonable inference that he assumes a framework of explanation that involves removing or mitigating surprise. Therefore, one would expect that the wording of the WAP (by Carter or anyone else) would vary in accordance with one's assumed theory of explanation. A rough approximation of the WAP without assuming any specific theory of explanation would be something to the effect of "our explanans for observational explananda must be restricted by the conditions necessary for our existence as observers."

One final ingredient went into the mix as Carter generated the WAP. It becomes clear that something is missing when comparing the WAP to the bundle of WAP_1 and WAP_2. Consider once more the reasoning involved in Leslie's Fishing Story: one can implement WAP_1 to determine the size of the fish that one can observe. And one can go a bit further still (as Leslie does) and employ WAP_2 to explain why one cannot observe (actually existing) fish bigger or smaller than that size. But surely it would not be claimed that the WAP (as formulated by Carter) is at work in this case. Leslie's purpose for telling the Fishing Story is, rather, to *simplify* the reasoning involved in WAP to a form which can be employed in an analogy to the case in which the WAP itself can actually be applied.

Note that cases of observation involve three pieces: the object(s) observed, the means of observation, and the observer. When selection effects are involved in observation, they thereby relate to some subset of the three pieces. WAP_1 addresses the means of observation. It dictates what one is capable of observing with one's tools and senses. WAP_2 addresses the object(s) observed. It dictates what one can explain about the set of observed objects and what one can extrapolate about the potentiality of unobserved objects (in conjunction with WAP_1). What most principles of reasoning involving observation tacitly take as assumed is the piece involving the

[8] Carter (1974), p. 295. Emphasis and parenthetical information included in original.

observer. For without the observer, it matters not whether there are objects or tools for observation. The recognition of this piece is exactly what differentiates the WAP from other principles of reasoning involving observational selection effects. The fact that this piece is overlooked in most cases as obvious speaks to the sentiment repeatedly expressed in the literature that the WAP is "trivial," "meaningless," and "a mere tautology." Nevertheless, it is this very component that sets it apart. Where others assume the ability of observation, the WAP highlights the *possibility* of observation itself by addressing the setting necessary for the observer's existence. This is WAP_3.

As with the other pieces of the WAP, Carter's use of WAP_3 arises from the Dicke-Dirac conversation. The centerpiece of Dicke's retort to Dirac is that there can be a principled justification for asserting that observers always will measure T to be within a restricted segment of the full continuum of the values of T. The principled justification is this: where there can be no observers, no observation of the value of T can be made. For values of T outside the restricted segment within which its value now lies, observers cannot exist. It is in this fashion that Carter saw the observational selection effect extended from a restriction on the tools and senses of the observer to the compatibility of the setting with the observer's existence.

WAP_3 is the portion of the WAP that Leslie glosses over in his Fishing Story. Only fish of a certain length can be observed (WAP_1), even though fish of many lengths exist in the lake (WAP_2). But it is not the case that the length of an observed fish is what dictates the existence of the observer fishing the waters. Rather, the setting of the story is straightforwardly assumed to be compatible with the existence of the angler; the setting is not tied to the length of the fish in the lake.[9] The omission of WAP_3 from the Fishing Story is why the WAP itself is not invoked as a means of reasoning about the fish, the observer, the apparatus, or any other part of the story. Instead, a combination of WAP_1 and WAP_2 is invoked, and Leslie intends for the reader to analogize the Fishing Story to the case where the WAP applies by adding WAP_3 to the recipe that comprises the multiverse case.

But clarification is in order. The existence of observers is not the crucial feature sought by WAP_3. If that were the case, the WAP would become unnecessarily anthropocentric. Instead, the restriction imposed by WAP_3 is one that speaks to *observer-compatible settings*. This falls in line

[9] To see this even more clearly, imagine that a fish suddenly jumped into the observer's boat. If this fish were longer or shorter than the length of fish capable of being caught with the observer's apparatus, surely Leslie would not maintain that his story would have the observer cease to exist. This is where the analogy fails.

with the widely recognized criticism of Carter's WAP that it is a "misnomer" in the sense that it could just as well have been titled in accordance with any of the other entities whose existence become possible once the setting is compatible with the existence of observers. John Earman, for instance, writes that "the selection function is served just as well by the existence of stars and planetary systems supporting a carbon-based chemistry but no life forms."[10] It is exactly this sort of "selection function" that is captured by the WAP_3 component of Carter's WAP; it is the *setting* that is the focus, not the (potential) observers or any of their anthropocentric qualities (or lack thereof).

These three pieces (WAP_1, WAP_2, and WAP_3) came together for Carter when he assembled the WAP. However, those very pieces were put together in much the same fashion by Immanuel Kant almost two centuries earlier.

In a work published in 1755, Kant presents his philosophy of cosmology, which he bases upon his interpretation of Isaac Newton's *Principia*. When discussing the likelihood that planets exist beyond Saturn, Kant writes:

> One would, therefore, according to this conjecture hope perhaps for the discovery of new planets beyond Saturn which would be more eccentric than this and also be closer to the cometary feature; but precisely because of this one would have a glimpse of them only for a brief time, namely, at the time of their [being in the] vicinity of the sun, which circumstance, together with the smaller measure of approach and the weakness of light have impeded so far their discovery and must make it difficult even in the future.[11]

The discussion involves a physical value, namely the number of planets (hereafter denoted P), which could conceivably have taken any particular (non-negative integer) value. However, Kant reasons that observers on Earth can formulate a principled justification for restricting the value to P. That principled justification is that observers are restricted in their vantage point to Earth-bound locations, which limits both the time and perspective of scale within which observers can glimpse undiscovered "planets" and witness a different value of P. This nicely lines up with Dicke's reasoning concerning the physical value of T, which played the role of WAP_1 in Carter's creation of WAP.

Kant does not stop after merely identifying the observational selection effect. He proceeds to implement it in a fashion remarkably similar to the fashion in which Carter implements the

[10] Earman (1987), p. 309.
[11] Kant (1981), p. 109-110.

observational selection effect identified by Dicke. Specifically, Kant extends the reach of the observational selection effect to the conditions necessary for the existence of the observer:

> It becomes evidently clear from all this that the forces of the human soul become hemmed in and impeded by the obstacles of a crude matter to which they are most intimately bound; but is even more noteworthy that this specific condition of the stuff has a fundamental relation to the degree of influence by which the sun in the measure of its distance enlivens them and renders them adapted to the maintenance of animal economy [regimen]. This necessary relation to the fire, which spreads out from the center of the world-system to keep matter in the necessary [degree of] excitation, is the basis of an analogy which will be firmly stated in respect to the different inhabitants of planets; and in virtue of that relationship each and any class of theirs is tied through the necessity [necessary structure] of their nature to the place which has been assigned to it [that nature] in the universe.[12]

No doubt the particular details of the account—the makeup of the human soul and the specific features of Kant's cosmology—are not the features of this passage that warrant attention. Rather, the portion of interest is Kant's insistence that it is the nature of the evolution of his universe that ties each observer (via the material in its body) to its specific location in the universe. This argument has nearly identical structure to that advanced by Dicke in 1961, which Carter references in both his 1967 manuscript and his published 1974 work. The final sentence of the passage conveys nearly identical content (when screening out the details of Kant's cosmology) to that found in Carter's rendition of the WAP. There is no mistaking Kant's identification of the piece most frequently omitted in reasoning about observational selection effects: the *possibility* of observation itself owing to the conditions necessary for the observer's existence at a particular location in the universe. That is WAP_3.

Kant was now treading the path that Carter would travel almost two hundred years later. Kant recognizes that the pieces he has in place allow him to explain, within the context of the cosmology he has created, why observers exist in the regions of his cosmos that they do:

> The better one learns to know nature, the better will one realize that the general properties of things are not alien to and separate from one another…One will also forthwith recognize that the affinity is proper to them through the community of origin out of which they have together their essential properties created.
>
> And now to apply this repeated consideration to the present purpose. These general laws of motion, which in the world-system have assigned to the superior planets a distant place from the center of attraction and inertia, have placed them thereby also in the advantageous condition to display their formations at the farthest from the center of raw matter and therefore with greater freedom. They [those laws] have

[12] Kant (1981), p. 188. Bracketed adjustments are included in Jaki's translation.

> put them also in a regular relation to the influence of heat which, according to a similar law, also spreads out from that center. And it is precisely these regularities that make the development of celestial bodies in these faraway regions more unimpeded and the generation of motions depending on them much faster, and, to say it briefly, the system better established, so that finally the spiritual entities will have a necessary dependence on matter to which they are personally tied; therefore it is no wonder that the perfection of nature is affected from both sides in a single connection of causes and from the same foundations. This harmony, on closer reflection, is not something sudden and unexpected, and because the latter [spiritual] entities are, through a similar principle, embedded in the general disposition of material nature, the spiritual realm will be more perfect in the faraway spheres for the same reason by which the bodily [world] is [more perfect there].[13]

The latter portion of this passage unmistakably matches Carter's formulation of WAP with respect to explanation in terms of the elimination of surprise. In both cases, what is to be *expected*—both utilize the very same terminology—must be that location (and hence observation) within the universe is tied to the physical conditions compatible with that observer's existence. Reasoning of this sort *explains* (for both Kant and Carter) one's location in the universe. That satisfies WAP_2.

So, by disassembling Carter's WAP into its constituent components (WAP_1, WAP_2, and WAP_3), we are in position to witness the full set of considerations and argumentative pieces that form its framework. However, when performing that analysis with a thorough backdrop of historical context, a much richer representation of the reasoning emerges.

John Barrow and Frank Tipler have generated what is considered to be the most exhaustive tome on the historical usage of the Anthropic Principle in cosmology.[14] They mention Kant's *Universal Natural History and Theory of the Heavens* in exactly one paragraph of their 677-page volume, and that paragraph is spent elucidating Kant's cosmology, specifically with respect to his implementation of Newtonian physics within the cosmology.[15] So even here there is to be found neglect of this piece of Kant's corpus, just as it was largely ignored during his time. But it also becomes clear that a thorough historical foundation properly sets the stage for legitimate philosophical inquiry, since it is here with Kant that we see the first employment of anthropic reasoning of the type that is contemporarily prevalent in the discipline. Kant should be credited

[13] Kant (1981), p. 193-194. Bracketed adjustments are included in Jaki's translation.
[14] Barrow & Tipler (1986).
[15] Barrow & Tipler (1986), p. 620. Note also that Jaki's 1981 introduction to Kant's work (Kant (1981)) puts emphasis on Kant's incorrect and uninformed employment of Newton's physics within Kant's cosmological scheme.

with much of the precedence concerning anthropic reasoning, even if his is merely a sketch of the principles that take varied forms today. Furthermore, this does not in any sense diminish the contributions of Carter and those working since with these ideas; rather, the realization should be that Carter's work now becomes part of a tradition of thought that Kant pioneered. In that context, many avenues open that previously were not available. A tradition of thought offers the opportunity to study the successes and failures along the trajectory of that tradition of thought that a single, isolated piece of argumentation does not offer. Much can be learned from the struggle through time of a philosophical line of argumentation and its implications.

The particular uses of anthropic reasoning and its relationship to the multiverse hypothesis are topics for discussion later in this project. Here, though, is the proper place—within the context of the case study just presented—to recognize that the *history* of multiverse thought can contribute enormous elucidation to the *philosophy* of multiverse thought.

That is the foundation of this undertaking. For, just as it is currently maintained that the WAP is a contemporary construct initiated in the works of Carter and that historical analysis cannot offer insightful contributions to anthropic reasoning, so, too, it is the consensus of belief that the multiverse is a contemporary theoretical construct with little to be gained from historical analysis. However, just like the WAP, the multiverse is a concept with a tradition. The study of that tradition offers opportunities for progressing our means of reasoning about the multiverse. This project reveals the multiverse tradition and advances the means of reasoning about the multiverse in accordance with that tradition.

1
Introduction: A Series of Worlds

Recent advances in the philosophy of cosmology have been triggered by the reemergence of an old theoretical construct. Now labeled the *multiverse*, the structure is one that involves the existence of universes other than our own. In the past, the concept often was discussed in terms of the existence of "other worlds." With time, the terminology utilized by those writing in the field has become quite idiosyncratic, which often leads to confusion. The main task to be undertaken in this short introductory chapter is to standardize the terminology associated with the multiverse (Section 1.1) and typicality assumptions (Section 1.2). Doing so will provide sufficient conceptual clarity for the project's ensuing analysis. The chapter closes with an extremely brief synopsis of the contents of each of the remaining chapters (Section 1.3).

1.1 The Multiverse

There is no avoiding the central issue emerging from multiverse cosmology, which is its direct inconsistency with "standard" cosmology, or cosmology that is committed only to the existence of a single universe. As will be seen, the disagreement is rooted in the inherent inaccessibility of the other universes. Multiverse cosmologists, by their own admission, maintain this position. We have arrived, then, at the very point of departure: there are two competing cosmological camps, and they maintain separate positions with respect to the extant number of universes.

The two central hypotheses, respectively championed by those favoring the existence of a single universe and those favoring the existence of multiple universes, are:

UNIVERSE: The hypothesis that the universe contains the same combination of laws, parameters, and constants throughout its entirety.

MULTIVERSE: The hypothesis that our universe (and its combination of laws, parameters, and constants) is just one region within a spacetime structure that has the following features:

i. The spacetime structure is topologically connected.

ii. The spacetime structure contains many causally disconnected regions.
iii. The causally disconnected regions may exhibit different combinations of laws, parameters, and constants.

These formulations are thoroughly contemporary in nature; (i) and (iii), for example, would never surface within the ancient or modern eras.[1] Thus, it will take significant development (within this project) before we again reach the point where consideration of *MULTIVERSE* as a specifically defined hypothesis will undergo analysis.[2] The reasons for the specific inclusion of (i)-(iii) will become clear as the project proceeds, but even at this early stage their necessity is evident: for there to be other universes, those universes must be defined in a way that makes them separate from each other in some capacity. Components (i)-(iii) provide that capacity. Furthermore, the clauses separate "scientific" multiverse hypotheses from "philosophical" multiverse hypotheses, such as the modal realism hypothesis of David Lewis.[3] The subject matter of this project is the "scientific" group; this is the group that cosmologists advocate in contemporary scientific literature, and hence it is the group that should receive focus from philosophers of science.

Note further that *UNIVERSE* and *MULTIVERSE* differ primarily concerning (iii). There is no immediately evident reason to suppose that *UNIVERSE* fails to satisfy conditions (i) and (ii) of *MULTIVERSE*; the universe is, presumably, topologically connected, and there exist causally disconnected regions. Thus, the difference lies in (iii): *UNIVERSE* eschews (iii) by maintaining that the causally disconnected regions of the universe are structurally identical (they all possess the same laws, parameters, and constants), whereas the multiverse setting excludes the case where all regions are identical. Because (iii) allows the physical constants of the miniverses to vary, a story must be told that describes how each miniverse (and its constants) is generated.[4] Since many different stories are capable of performing this function, there exist many different instantiations of *MULTIVERSE*. These are the stories to be told in Chapters 2, 3, and 5.

The overarching aim of this study is not to make a definitive choice between *UNIVERSE* and *MULTIVERSE*. Understanding the distinction between the two is crucial, but the emphasis here

[1] Interestingly, (ii) is quite prevalent in those eras, though its denotation varies from era to era and theorist to theorist. See the corresponding discussion in Chapter 4 for more.
[2] We will not return to the formulation of the multiverse hypothesis as *MULTIVERSE* until Chapter 6.
[3] For example, note that Lewis's modal realism hypothesis does not satisfy clause (i).
[4] Note that I have implicitly switched to discussing just the physical constants, instead of the laws, parameters, and constants addressed by (iii). This is to shorten tedious phrasing. For the remainder of the project, it should be understood that reference merely to "laws," "parameters," or "constants" is implicitly a reference to all three, unless specifically noted in the context of the discussion.

will fall squarely on analyzing *MULTIVERSE*. It is a hypothesis with a history—a *bona fide* tradition filled with models and arguments that can inform careful thought about the present state of *MULTIVERSE*. This project presents that tradition and recognizes some of the implications—and limitations—that can be reached regarding *MULTIVERSE* via careful consideration of that tradition.

The idiosyncratic formulations of the multiverse hypothesis present a problem for undertaking consistent analysis. For example, many seventeenth-century writers considered stars to be harbingers of "other worlds," whereas contemporary writers (if they employed such language) would undoubtedly include the stars as part of *our* world. It is a difficult task to generate a consistent set of desiderata that encompasses all historical multiverse constructs.

Nevertheless, the multiverse concept—in any of the eras—is one that is readily recognizable. There are thoroughly crafted examples in the scientific literature from the ancient and Renaissance eras, for example.[5] It has unmistakable pieces: separate, inaccessible regions that together comprise the multiverse. Thus, whereas the meaning of "separate" and "inaccessible" may change according to the context within which a writer postulates a multiverse, it remains true that any multiverse necessarily includes regions of this sort. So, while a contemporary multiverse theorist might discuss a multiverse as a spacetime structure that is topologically connected with many causally disconnected regions (*MULTIVERSE* (i) and (ii)), an ancient multiverse theorist might describe reality as comprised of many worlds separated by—but still contained within—the same overarching space. Both have the same idea in mind; both refer to a multiverse.

When discussing the multiverse, the term 'miniverse' will be used to denote each of the separate disconnected pieces—earths, worlds, spacetime regions, universes, etc.—of the cosmology.[6] Therefore, 'miniverse' is a blanket generalization that is contextualized according to the theory under consideration: it could represent another earth, another solar system, another spacetime region, another universe, etc. For a multiverse theorist, it is the *multiverse* that comprises the entirety of what exists; our universe resides within the multiverse. Thus, for the

[5] I take the "scientific era" to include the ancient Greeks. Though this is debatable, the debate would be merely semantic; the important point is that some ancient Greeks developed multiverse cosmologies.
[6] The term 'miniverse' is borrowed from Earman (2009 ms.), which is the only place I have encountered it. Its usefulness (in my opinion) makes it only a matter of time before it (or a substitute term for the same concept) will become standard jargon in the discipline.

remainder of the project, 'universe' will denote *our* miniverse.[7] It is the portion of nature in which we reside. Note that the universe is an *entire* miniverse: though we are able to gather observations in a *piece* of the universe, there are regions of it for which we cannot gather observations, though we might be able to gather them in the future.

In this fashion, it becomes clear that 'multiverse' is a concept that is, in part, derivative of 'miniverse': a multiverse is a cosmological model that postulates more than one miniverse. But a multiverse is more than merely a collection of miniverses. A multiverse is a collection of miniverses that are related to each other in a certain way. For instance, the miniverses might be separated from each other by vast expanses of space that cannot be traversed, or they might be located in different dimensions.[8] Regardless, the miniverses are separated *somehow*. This means that any multiverse is defined in part by two standard features, namely by a collection of miniverses and a rule of separation that dictates the relationship of miniverses to each other. These two features will factor prominently in the classification scheme developed in Chapter 4.

Further, each multiverse instantiation also can be differentiated from its counterparts with respect to the way that it generates new miniverses. This feature of a multiverse will be referred to as the *miniverse generation mechanism*. The miniverse generation mechanism is an indispensable piece of its corresponding multiverse, so there is good reason for including it as a third important "standard feature" comprising a multiverse model. The miniverse generation mechanism is a concept that traces back as far as the ancient era, as will be seen in Chapter 2.

Of the three features, the miniverse generation mechanism is the most idiosyncratic. It is nearly always tailored to the specific multiverse under consideration, whereas many multiverses share the same separation rule and all participate generally in including a collection of miniverses.

One further introductory note is in order concerning terminology and the slew of models that will come forth in the following chapters. The prefix "historical," when used to reference the models in the multiverse tradition, is meant to refer to *all* multiverse models. That is, "historical multiverse models" denotes all multiverse models, including contemporary ones. I explicitly note

[7] The exception to this usage will be when the terms (or rather, their idiosyncratic correlates) are used in direct quotations. I will leave the passages as they were published to maintain authenticity and to display the full flavor of the multiverse tradition.
[8] There are other multiverse speculations on offer that propose additional ways of separating the miniverses. These models will be displayed in Chapters 2, 3, and 5, and a classification scheme for sorting them will be proposed in Chapter 4.

this because I wish, at this very early stage, to begin the process of unifying all of the threads of multiverse thought—whether they be ancient, contemporary, or somewhere in between—into a single tradition of thought.

1.2 Typicality Assumptions

Theorizing about celestial happenings in the scientific era has been polarized by assumptions about whether the parts of the Universe that we cannot observe are fundamentally similar to, or different from, the parts that we can observe. Assumptions of this sort will be referred to as *typicality* assumptions. The concept is self-explanatory: a theory makes a *Typicality* assumption if it maintains that the unobserved is the same as (or at least can be approximated by) the observed. Put most simply, what we observe *is typical* of all that exists. Contrastingly, a theory makes an *Atypicality* assumption if it maintains that the unobserved is fundamentally different from the observed. Put most simply, what we observe *is atypical* of all that exists.[9]

The definitions provided for the typicality assumptions are purposefully generalized. This permits the terminology to capture, as broadly as possible, the various instantiations of typicality assumptions that are implemented both within cosmology generally and within the multiverse tradition specifically. For example, there are various senses in which one could claim that the evidence gathered thus far from our observations is typical of the evidence that would be gathered anywhere in the universe (if collecting such evidence were possible). One common example from standard cosmology that will receive repeated attention in this project is the Cosmological Principle. The Cosmological Principle is the claim that the universe, when viewed in its vastness, is homogeneous and isotropic. Because the Cosmological Principle posits that the unobserved regions of the universe are similar to the observed regions, it is an instantiation of the Typicality assumption.

Likewise, for multiverse cosmologists, there are various senses in which one could claim that the universe is typical—or atypical—of its counterpart miniverses. For the sake of gaining familiarity with the terminology that will be implemented throughout the project, note that a claim

[9] To avoid confusion, I will use capital letters when explicitly referencing one assumption or the other, as in "This theory makes a Typicality assumption…" This is to be contrasted with references to the general concept of such assumptions, which could be of one form or the other. References of the latter sort will be written in lower-case letters, as in "Let us see whether this theory makes any typicality assumptions."

positing a likeness between the universe and other miniverses is a Typicality assumption, and a claim positing a distinction between the universe and other miniverses is an Atypicality assumption. Generalized claims that refer to either sort of relationship are merely typicality assumptions.

With respect to multiverse cosmological models proposed in the scientific literature, typicality assumptions (and their implications) hitherto have been largely ignored. A significant portion of this project involves following the thread of typicality assumptions through the instantiations of multiverse cosmologies that have been proposed.

1.3 The Map

The project is broken into two fundamental pieces, one historical and one philosophical. The historical piece is comprised of Chapters 2-5. Those chapters present a multitude of models from the ancient (Chapter 2), modern (Chapter 3), and contemporary (Chapter 5) eras. Included within the historical piece of the project is a classification scheme for sorting multiverse models objectively (Chapter 4).

The philosophical piece of the project is comprised of Chapters 6-9. Those chapters synthesize the extant argumentation in favor of the multiverse (Chapter 6), demonstrate how the extant argumentation is reliant on typicality assumptions (Chapter 7), and expose the foundational justificatory problems facing the tradition owing to the reliance on typicality assumptions (Chapter 8). Finally, in departure, the lessons learned—both historical and philosophical—are addressed, and suggestions for finding the path forward are considered (Chapter 9).

2
Ancient Multiverse Models

There is a prevailing tendency in the contemporary philosophy of physics literature to disregard (or misconstrue) the historical underpinnings of the multiverse concept.[1] The multiverse is viewed as a new construct and the next in a logical procession of cosmological models. Bernard Carr, for instance, writes in the introductory passage to his anthology that "what we regard as the 'Universe' has constantly changed as scientific progress has extended observations outward to ever larger scales and inwards to ever smaller ones."[2] He then describes how cosmological developments throughout the ages have proceeded from a geocentric view to a heliocentric view, then to a galactocentric view, then to a cosmocentric view, and finally, now, to a multiverse view. While his focus is not historical in that work, the lack of mention of any historical multiverse thinkers is, nevertheless, surprising.

Furthermore, it is a mistake. It is a mistake because many of the conceptual parameters of the multiverse already have been explored. Failing to engage with the previous historical developments of the multiverse makes one vulnerable not only to making the same mistakes as one's predecessors but also to failing to recognize significant underlying assumptions that come to the fore when sifting through the annals of the multiverse. There is an historical lacuna to be filled concerning the conceptual development of the multiverse, and the historical lacuna, once filled, has large potential for making clear some philosophical aspects of the contemporary multiverse concept.

It would be anachronistic to refer to the ancients and those of the Renaissance and modern eras as 'multiverse theorists.' It even may be anachronistic to refer to some of those from the contemporary era as 'multiverse theorists.' Nevertheless, I think it worthwhile to associate them all in this way, since they all draw upon a very similar concept in their cosmologies. The similarity

---

[1] See, for instance, Robles-Pérez et al. (2007) for a misconstrual: "Actually, it was Giordano Bruno who first realized that many other worlds other than ours could exist." As will be discussed, the multiverse concept traces back much further than Bruno. To that end, see the references provided in Chapter 4 for the few surveys I have encountered that link the historical multiverse with the present concept.

[2] Carr (2007a), p. 7.

lies in the theoretical proposal of other earths, other worlds, other universes, or otherwise inaccessible places of existence; the terminology and the specific denotation vary from theorist to theorist. Thus, some term needs to be used to encompass the likeness, and with no reason to introduce the clutter of a new term, I have chosen to stick with 'multiverse theorist.'

The inner workings of historical multiverse argumentation are the jewels to be extracted, but first the ore must be mined. To that end, the goal of this chapter and the three that follow it is to convey the historical landscape of multiverse thought with the aim of generating a classification heuristic. A catalogue of multiverse thinkers, including the details of each thinker's multiverse, is the first step. For now, the context of each multiverse is ignored; this includes why the multiverse was postulated, what typicality assumptions are involved, and other relevant contextual facets. Such information will be important in the final analysis, but here it is bracketed for the purpose of first introducing the historical multiverse models themselves. Then, in the subsequent chapters, the focus will shift to the philosophical details (and their implications) of the historical models. Hence, expectations of exhaustiveness need to be tempered: Chapters 2-5 will sufficiently serve the purpose of sketching the historical outline of the multiverse tradition, but it will fail to fill in the fine details. Those details which are necessary will show themselves in the proper (later) portions of the project.

Though a general theme concerning the structures of multiverse models will emerge, it is important to take note that this effect manifests itself only over the full set of models—from the ancients through contemporary theorists. Thus, there is no sense in which historical multiverse models "build upon" each other, despite the fact that there are unquestionable instances of influence in certain cases.[3] The immediate effect is a residual number of threads left loose to be tied as the project proceeds. It is not unhelpful to envision these first few chapters as a "gathering" of the threads necessary for the full task, some of which are immediately tied in and some of which are merely identified for inclusion later in the project.

Because it is essential to impart familiarity with the many multiverse models (in addition to familiarity with the thinkers themselves), I have included a concise excerpt from the writer's primary multiverse material whenever possible. This should help to convey what paraphrasing sometimes cannot, which is the visualization of cosmological models rife with idiosyncrasies concerning the definition of and relationship between miniverses. Nevertheless, the intention in

[3] Trimble (2009) also expresses this sentiment.

what follows is not historical dissection and analysis. (Extensive references to the primary and secondary literature are provided for each thinker for those interested in that form of investigation.) Instead, the focus lies on establishing a tie between contemporary multiverse thought and that of historical lore through the activity of assimilating a concise compendium of multiverse thought in a single location. This will make possible a classification system that captures all historical models and likewise accommodates the contemporary models. For that purpose, it suffices here to introduce each of the historical cases only to the extent that the broad structure of the multiverse in that case becomes evident.

The multiverse tradition can be traced back as far as the ancient Greeks. Though most of the theories are preserved now only in fragments and secondary accounts, there is little dispute that the existence of multiple universes is a possibility considered by several different thinkers. The following are small synopses of each of those ancient accounts in which there exist glimmers (and in some cases, clear depictions) of the multiverse.

2.1 Anaximander (c.610-c.546 BC)

As is frequently the case when dealing with the works of the ancients, our knowledge of Anaximander's teachings comes from proximate, but nevertheless secondary, sources. Taking the lone extant fragment of Anaximander's thought (couched in paraphrase from Simplicius and derived from Theophrastus) as a guide, it can be seen that Anaximander postulates a multiverse of sorts:

> He says that it [the element of existing things] is neither water nor any other of the so-called elements, but some other *apeiron* in nature, from which come into being all the heavens and the worlds in them. And the source of coming-to-be for existing things is that into which destruction, too, happens 'according to necessity; for they pay penalty and retribution to each other for their injustice according to the assessment of Time,' as he describes it in these rather poetical terms.[4]

The small quotation at the end of the passage is all that is directly attributed to Anaximander, which makes it difficult to argue unequivocally for his belief in the multiverse. As such, the historical analysis does not come to consensus concerning his multiverse stance.[5]

[4] Kirk, Raven, & Schofield (1983), pp. 107-108.
[5] There is debate about whether Anaximander subscribed to miniverses that were successive in nature or co-existent in nature (or, indeed, whether Anaximander subscribed to a multiverse at all). Historians Zeller (argued for

However, if our lead is taken from the temporally closest subset of secondary sources on Anaximander, including those from which the above quotation derives, Anaximander believes in miniverses that are temporally successive in nature.[6] The passage hints at this when it speaks of "worlds" (in the plural form) and the fact that coming-to-be and destruction are inherent qualities of all things (including, presumably, the "worlds"). This is the interpretation provided by Theophrastus and Simplicius, from whose works the fragment survives.

Unfortunately, little else is discernible with respect to Anaximander's multiverse. It is known that he advocates infinite space, and also that the space is filled with some form of "original matter" (the *apeiron*). However, whether the supposed miniverses form in a fashion akin to those that form in the atomistic multiverse is not readily apparent.[7] One distinct possibility can be gleaned from the account Anaximander gives (again, through the doxographers) of the formation of the universe. From Pseudo-Plutarch, the process was as follows:

> Something capable of generating Hot and Cold was separated off from the eternal [Boundless] in the formation of this world, and a sphere of fire from this source grew around the air about the earth like bark around a tree. When this sphere was torn off and closed up into certain circles, the sun and moon and stars came into being.[8]

If one trusts Theophrastus and the other doxographers in their assessment that Anaximander advocated multiple miniverses, and the reasonable assumption is made that the other miniverses form in the same manner in which the universe was formed, then the general parameters of Anaximander's multiverse begin to take shape. The fragment containing the direct quotation from

successive) and Burnet (argued for co-existent) conversed in the literature about the subject in the early 20th century. See Burnet (1920). Cornford (1934) settled the issue in favor of successive miniverses, though Kirk (in Kirk (1955) and Kirk, Raven, & Schofield (1983)) argues that it may be most plausible to maintain that Anaximander did not believe in multiple miniverses at all. Kahn (1994), p. 47-53, also expresses doubt about which view (if either) Anaximander subscribed to. The predominant argument against the multiverse for Anaximander rests in the claim that those of the doxography were "tainted" by the works of their contemporaries, the stoics and the atomists, to the point that in their accounts of predecessors like Anaximander, they anachronistically assigned a belief in multiple miniverses. See, for instance, Kirk (Kirk, Raven, & Schofield (1983)) and Kahn (Kahn (1994)), who maintain that Theophrastus and others of the doxography misattributed multiple universes to Anaximander.

[6] To clarify a point from footnote 5: the doxographers *did* assign a belief in the multiverse to Anaximander. The contemporary debate concerns whether that belief was well-founded (or whether it was anachronistic).

[7] The atomistic multiverse first surfaces in the teachings of Leucippus and Democritus. Their views will be presented later in the chapter.

[8] Kahn (1994), p. 85-86.

Anaximander makes mention of the eventual demise, back into the *apeiron*, of the miniverses. It is perhaps from this continual emergence and destruction that the miniverses are described by Anaximander's successors as successive, rather than co-existent, in nature.[9]

2.2 Heraclitus (c.540-c.480 BC)

In contrast to the case of Anaximander, an appreciably large corpus of fragments exists from the original works of Heraclitus, although many are akin to the fragment of Anaximander in the sense that they are couched within paraphrases or exhibited as quotes presented by the successors of Heraclitus.[10] As was also the case in the historical interpretations of Anaximander's work, there is discord among historians concerning Heraclitus's complete cosmological outlook. The chief debate is whether Heraclitus subscribed to ecpyrosis (by which miniverses would successively emerge and be destroyed by fire).[11]

Here, the adopted stance will coincide with the interpretation in the doxography (namely, that Heraclitus *did* subscribe to ecpyrosis). In that spirit, passages sketching the parameters of Heraclitus's multiverse include fragment 30, written by Clement of Alexandria, which reads (in part):

> Heraclitus the Ephesian is most clearly of this opinion [sc. that there will some time be a change into the essence of fire]; he considered that the world in one sense is eternal, but in another sense is in the course of destruction, knowing that the world of this world-order is none other than a modification of the eternal world. But that he knew that the world exclusively as such, composed of all reality, is eternal, he makes clear by these words: *This* (world-) *order* (the same of all) *did none of gods or men make, but it always was and is and shall be: an ever-living fire, kindling in measures and going out in measures.*[12]

[9] It is not clear why several co-existent miniverses could not simultaneously perform the emerge-and-disappear process, thereby forming co-existent miniverses rather than successive ones. Perhaps the doxographers had in mind only Anaximander's process as it pertained to the string associated with the universe, while at the same time ignoring the similar process that may be taking place simultaneously in other parts of the would-be multiverse.
[10] Kirk (in Heraclitus (1962)) lists more than 100 fragments dealing with the cosmic account of Heraclitus, which he estimates comprise approximately half of all surviving fragments of Heraclitus's work.
[11] As in Anaximander's case, the prevailing argument against ecpyrosis (and therefore against a multiverse) in the cosmology of Heraclitus involves the potential for an anachronistic taint in the writings of the doxographers due to the influence during their time of the atomistic and stoic doctrines.
[12] Heraclitus (1962), p. 307. Kirk's editing is such that the writing of the doxographer is in italics and that of Heraclitus in standard font, but to properly accentuate the quote by Heraclitus I found it better to reverse Kirk's convention.

The careful indication by Clement that the term "world" can take on multiple meanings (and his further assertion that it *does* take on multiple meanings for Heraclitus) provides most of the necessary framework for generating the multiverse of Heraclitus. The "eternal" sense of the word indicates that Heraclitus does not postulate simultaneously existing miniverses, and the second sense—that the world is in the course of destruction—indicates that the miniverses themselves come to be and decay in temporal succession.

Heraclitus maintains that fire, sea, and earth are the three cosmological elements, though fire reigns supreme as the element from which and to which everything continually cycles. This remains true even of the miniverses themselves, as Plutarch intimates in fragment 90:

> For as Heraclitus says that the principle which orders the whole by gradually changing makes the world out of itself and again itself out of the world, and *All things are an equal exchange for fire and fire for all things, as goods are for gold and gold for goods*.[13]

Indeed, Aristotle echoes the sentiments expressed in the two preceding passages. He attributes to Heraclitus a multiverse with ecpyrotically-delineated miniverses:

> All thinkers agree that it [the world] has had a beginning, but some maintain that having begun it is everlasting, others that it is perishable like any other formation of nature, and others again that it alternates, being at one time as it is now, and at another time changing and perishing, and that this process continues unremittingly. Of this last opinion were Empedocles of Acragas and Heraclitus of Epheseus.[14]

This solidifies the claim, at least within the doxography, that Heraclitus envisioned a multiverse with miniverses that were separated temporally, generated by fire, and destroyed by fire.

2.3 Empedocles of Acragas (c.494-c.434 BC)

Upon reviewing the passage just recited from Aristotle, one expects the theory of Empedocles to be of a likeness with that of Heraclitus. And, like that of Heraclitus, the cosmology presented by Empedocles is fairly well-preserved. As basic building blocks, Empedocles takes fire, water, earth, and air, and he includes an attractive action (which he labels 'Love') and a repulsive action (which he labels 'Strife'). To this framework Empedocles stipulates that nothing can be created and nothing can be destroyed, but this stipulation applies merely to the elements themselves; that

[13] Heraclitus (1962), p. 345.
[14] Aristotle (1986), p. 97.

which is *composed of* the elements is subject to continual creation and destruction due to the influence of Love and Strife.[15]

Beginning with a state akin to the *apeiron* described by Anaximander, Empedocles describes a process by which the four elements first become maximally united (due to Love) then become maximally separated (as Strife gains sole reign). This appears to correspond to alternating states in which the elements are completely mixed together (when Love is maximal) and then completely separated into layers (when Strife is maximal), with all of the earth at the core, surrounded by all of the water, then all of the air, and finally all of the fire.[16] This cycle continues for all of time, with each complete cycle exhibiting some time periods like the present during which enough Love is at work to permit the elemental mingling necessary for the emergence of humans and other beings.[17]

The framework of Empedocles thus falls in line with the parameters of the multiverse. The miniverses are the individual cycles. Empedocles further develops the details in what Wright dubs "the longest and most important of the extant fragments," part of which reads:

> All these are equal and of like age, but each has a different prerogative, and its particular character, and they prevail in turn as the time comes round. Moreover, nothing comes to birth later in addition to these, and there is no passing away, for if they were continuously perishing they would no longer exist. And what would increase this whole, and from where would it come? How would it be completely destroyed, since nothing is without them? No, these are the only real things, but as they run through each other they become different objects at different times, yet they are throughout forever the same.[18]

The way in which they (the miniverses) are "forever the same" is through their link to each other as part of a well-defined set, which in the present terms is nothing other than a multiverse.[19]

Thus, whereas the ancient doxographers by and large concluded—perhaps erroneously, by contemporary accounts—that Anaximander postulated successive miniverses, there appears to be fairly decisive surviving primary material that links Empedocles to that very hypothesis.

[15] For an exhaustive study of the cosmological account of Empedocles, see O'Brien (1969).

[16] There is contention about this point, however. See Wright's introduction to Empedocles (1981), especially pp. 40-48, for further references to the literature.

[17] Aristotle and others who wrote about the work of Empedocles generally agreed that the present era is one in which strife is gaining hold after the period completely ruled by love, though it could be argued (as some did) that we are witnessing the era of increasing love after strife held sway.

[18] Empedocles (1981), pp. 166-167.

[19] Though additional argumentation would be required to alleviate concerns of anachronistic attribution of the concept, this sort of ancient reasoning plays the role that topological connection plays in contemporary multiverse models. Thus, Empedocles satisfies condition (i) of the multiverse definition presented in Chapter 1.

Additionally, we gain a glimpse of the internal constituents of Empedocles's multiverse through writers such as Aristotle, who further notes in his *Physics* that "Empedocles, for example, appeals to luck when he says that air is separated out on top, not always but as luck has it; at least, he says in his cosmogony that 'it happened to run that way at that time, but often otherwise'."[20] With Empedocles, then, we appear to have the first tangible emergence of a miniverse generation mechanism, even if that mechanism is mere luck.[21] Where Anaximander and Heraclitus merely *describe* the generation of miniverses, Empedocles expresses a modicum of detail concerning a component in play during that action.[22]

2.4 Leucippus (?) and Democritus (c.460-c.370 BC)

The influence of the atomistic cosmology stretches temporally further than any other single thread of influence in the multiverse tradition. In that sense, each of the subsequent atomistic accounts of the multiverse follow the lead of Leucippus and Democritus.[23] Though the founders of atomism leave no surviving primary fragments of their multiverse thought, no reputable interpretation (from either the ancient doxographers or any of the subsequent historians) fails to attribute to them belief in multiple miniverses.[24] Of Leucippus, Diogenes Laertius conveys the following:

> Leucippus holds that the whole is infinite…part of it is full and part void…Hence arise innumerable worlds, and are resolved again into these elements. The worlds come into being as follows: many bodies of all sorts of shapes move 'by abscission from the infinite' into a great void; they come together there and produce a single whirl, in which, colliding with one another and revolving in all manner of ways, they begin to separate apart, like to like. But when their multitude prevents them from rotating any longer in equilibrium, those that are fine go out towards the surrounding void as if sifted, while the rest 'abide together' and, becoming entangled, unite their motions and make a first spherical structure.[25]

[20] Aristotle (1995), p. 106.
[21] The concept of the miniverse generation mechanism will be explored at length in Chapter 7.
[22] Of course, the component in play is only luck, and this comes down to us only secondarily through Aristotle, but nevertheless there is a difference between this and simple description of miniverse formation.
[23] The explicit details of the atomistic doctrine leading to the multiverse will be presented in Chapter 6; the context there will be the multiverse as an implication of the physical theory adopted by the theorist.
[24] By way of example, Kirk, who is among the most reliable of the contemporary historians of ancient philosophy, claims that "they are the first to whom we can with absolute certainty attribute the concept of innumerable worlds" (Kirk, Raven & Schofield (1983), p. 419).
[25] Kirk, Raven, & Schofield (1983), p. 417.

Likewise, we hear from Hippolytus that Democritus advocates essentially the same cosmological scheme as his mentor:

> Democritus holds the same view as Leucippus about the elements, full and void…he spoke as if the things that are were in constant motion in the void; and there are innumerable worlds, which differ in size. In some worlds there is no sun and moon, in others they are larger than in our world, and in others more numerous. The intervals between worlds are unequal; in some parts there are more worlds, in others fewer; in some increasing, some at their height, some decreasing; in some parts they are arising, in others falling. They are destroyed by collision one with another. There are some worlds devoid of living creatures or plants or any moisture.[26]

The preceding two passages, which attribute multiverse belief to Leucippus and Democritus, are noteworthy in two ways. The first item of note involves the description of what amounts to a miniverse generation mechanism by Leucippus in the passage written by Diogenes Laertius. Empedocles, as flagged earlier by Aristotle, surmised that the generation of miniverses involved some semblance of—and perhaps even predominantly—luck. But here we see not only an account dedicated exclusively to addressing the fact that multiple miniverses exist, but also an attempt at explicating exactly how a "new" miniverse arises. Further details of the atomistic miniverse generation mechanism will receive proper attention later, but this need not deter us from presently acknowledging the historical importance of Leucippus's detailed account.

The second item of note involves the collection of details in the second passage about the other miniverses of Democritus's theory. These details identify some of the ways in which the other miniverses differ from the universe. The slightest hint of the same sentiment was to be found in Aristotle's assessment of Empedocles: "it happened to run that way at that time, *but often otherwise*." Already, within the earliest recorded whispers of multiverse thought, we can see the supervening presence of typicality assumptions lurking in the shadows.

2.5 Diogenes of Apollonia (c.440 BC)

The cosmology of Diogenes, though predominantly an amalgamation of separate pieces of the cosmologies of his predecessors, is nonetheless important in the present context because one of the pieces that Diogenes chose to include from the theory of Leucippus is the existence of

[26] Kirk, Raven, & Schofield (1983), p. 418.

innumerable worlds. In that sense, he becomes one of the earliest in the long line of those influenced by the atomistic tradition.

Given the fact that the multiverse component was one piece among many that Diogenes selected from different influences, it may be disingenuous to place Diogenes among the atomistic "tradition." Nevertheless, there is evidence that bolsters the case for fairly substantial reliance on the atomistic doctrine:

> Diogenes the Apolloniate premises that air is the element, and that all things are in motion and the worlds innumerable. He gives this account of cosmogony: the whole was in motion, and became rare in some places and dense in others; where the dense ran together centripetally it made the earth, and so the rest by the same method, while the lightest parts took the upper position and produced the sun.[27]

Diogenes's position, here presented in the doxography by Pseudo-Plutarch, straightforwardly displays the influence of his predecessors, including the single-substance and constant-motion postulates adopted by Heraclitus (the latter made famous in his classic river example). From Leucippus, we see Diogenes accept not only the postulation of the multiverse, but also the "sifting" effect in miniverse generation.[28] Of even greater interest—further investigation of which will be temporarily postponed—is the apparent inclusion of the Typicality assumption with the claim "*and so the rest by the same method*." Diogenes, with this small piece of theorizing, again follows the lead of the atomists in expressing an early forerunner of the Typicality assumption.

This synopsis of Diogenes, though exceedingly brief, suffices to convey his importance in multiverse tradition. The apparent lack of substantial originality need not overshadow his inclusion in the tradition; such an oversight no doubt could be counted among the reasons for the present lack of a comprehensive compendium of multiverse thought. Indeed, other "well-entrenched" multiverse theorists of the ancient era might be said to be even "less original" than Diogenes in the sense that they straightforwardly adopt the entire atomistic doctrine.[29]

---

[27] Kirk, Raven, & Schofield (1983), p. 445.
[28] For direct argumentation that Diogenes was influenced by Leucippus, see Kirk, Raven, & Schofield (1983), pp. 440-446.
[29] See, for instance, the discussions of Epicurus and Lucretius in what follows.

2.6 Epicurus (341-270 BC)

The shift in focus to the writing of Epicurus brings with it an escape from the necessary reliance on the doxography. By contrast to those of earlier figures, the thoughts of Epicurus come to us largely in his own words, and with the authenticity also comes quantity. This means that Epicurus stands as the first multiverse theorist from whom we receive not only the postulation of a multiverse, but also direct pieces of argumentation in its favor.

An atomist through-and-through, Epicurus becomes the anchor of influence for many in the multiverse tradition, including Lucretius and Giordano Bruno. Initiating what transpires into a running theme for those thinkers, Epicurus writes to Herodotus that

> There are infinite worlds both like and unlike this world of ours. For the atoms being infinite in number, as was proved already, are borne on far out into space. For those atoms, which are of such a nature that a world could be created out of them or made by them, have not been used up either on one world or on a limited number of worlds, nor again on all the worlds which are alike, or on those which are different from these. So that nowhere exists an obstacle to the infinite number of the worlds.[30]

This passage admits of several tendrils, each of which is quite crucial to the multiverse tradition. Epicurus opens with the declaration that he subscribes to a multiverse theory, and by using the particular words he uses, he effectively takes on a typicality assumption.[31] Next, he creates a short argument for *why* there exists a multiverse. This is the first of its kind—an explicit primary account of multiverse argumentation—though there can be no mistaking the fact that Epicurus relies heavily on the earlier atomists (Leucippus and Democritus) for his conjecture. The structure of the argument is such that it draws upon Epicurus's assumed theory of physics (in his case, atomism) as a crucial premise; this, too, will prove representative of one of the major argumentative styles associated with multiverse thought.[32]

The substantial surviving primary material from Epicurus also contributes considerable insight of a type not afforded by multiverse theorists who came before him. Consider, for instance, the following passage, taken from a letter to Pythocles:

> A world is a circumscribed portion of sky, containing heavenly bodies and an earth and all the heavenly phenomena, whose dissolution will cause all within it to fall

[30] Epicurus (1979), p. 25.
[31] I do not yet want to commit to the claim that Epicurus takes on *the* Typicality assumption. Instead, I postpone that determination until Chapters 7 and 8, where the spotlight will belong entirely to typicality assumptions.
[32] See Chapter 6.

> into confusion: it is a piece cut off from the infinite and ends in a boundary either rare or dense, either revolving or stationary: its outline may be spherical or three-cornered, or any kind of shape. For all such conditions are possible, seeing that no phenomenon is evidence against this in our world, in which it is not possible to perceive an ending.[33]

The passage sets Epicurus apart, even from the atomists from whom so much of his multiverse is derived, because it is the first instance in which a theorist takes pains to specifically articulate the defining features of a miniverse in his theory. Of course, sketching the parameters of the miniverses within one's multiverse becomes standard fare for subsequent theorists, so it is reasonable to presume that the theories of those who came before Epicurus likewise contained similar information. But given that no such passages have survived, we can be left only to note that Epicurus claims precedence in this respect.[34]

Epicurus goes still a step further by affirming, in the final sentence of the passage, a feature of miniverses that becomes the backbone of the multiverse tradition: the miniverses are entirely inaccessible from each other. The specific connotations built into the term "inaccessible" vary subtly from theorist to theorist, but the separation of miniverses is a necessary hallmark of multiverse theory. Epicurus, to eliminate any doubt about the matter, goes so far as to claim about the relationship between miniverses that

> it is not merely necessary for a gathering of atoms to take place, nor indeed for a whirl and nothing more to be set in motion, as is supposed, by necessity, in an empty space in which it is possible for a world to come into being, nor can the world go on increasing until it collides with another world, as one of the so-called physical philosophers says. For this is a contradiction of phenomena.[35]

There can be no question that the "contradiction of phenomena" is the confusion that would be inherent if "two" miniverses were permitted to collide; a paradox would ensue, one with equally weighty arguments to support both the side claiming that there really only exists one miniverse in this scenario and the other side claiming that there remain two miniverses.[36]

---

[33] Epicurus (1979), p. 59. See also p. 47, from the letter to Herodotus, for another rendition of miniverse formation. That passage also includes matters of import for typicality assumptions in the case of Epicurus, and so it will be returned to in the proper place.

[34] Additionally, the variety of miniverses described by Epicurus provides an exemplar of ancient thought regarding condition (iii) of the multiverse definition provided in Chapter 1.

[35] Epicurus (1979), p. 61. The "so-called physical philosopher" to which Epicurus refers is believed to be either Leucippus or Democritus; see Bailey's notes on pp. 284-285 of Epicurus (1979). Epicurus appears to require more conditions for miniverse creation than do his predecessors. This will be addressed in Chapter 3 during the discussion dedicated to the multiverse as an implication of physical theory.

[36] Unquestionably, this reasoning by Epicurus satisfies condition (ii) of the multiverse definition generated in Chapter 1.

2.7 Lucretius (c.100-c.50 BC)

Following the chain of atomistic influence, we see with Lucretius the most ardent of the followers of Epicurus's doctrine. Lucretius carefully—but in the colorfully descriptive way of the poet—reasserts the atomistic teachings of Epicurus, including Epicurus's departures from the earlier doctrine of Leucippus and Democritus.[37] Of course, in the present discussion, the crucial piece of atomism that Lucretius adopts is the multiverse doctrine.

After establishing (to his satisfaction) that space is infinite and that the number of indestructible atoms is likewise infinite, Lucretius concludes that the limits of the world—the earth, sky, stars, and all other things grasped by the senses—could in no way comprise the entirety of what exists.[38] The formation of the universe cannot exhaust the infinite store of atoms. Thus, writes Lucretius:

> *It is in the highest degree unlikely that this earth and sky is the only one to have been created* and that all those particles of matter outside are accomplishing nothing. This follows from the fact that our world has been made by nature through the spontaneous and causal collision and the multifarious, accidental, random and purposeless congregation and coalescence of atoms whose suddenly formed combinations could serve on each occasion as the starting-point of substantial fabrics—earth and sea and sky and the races of living creatures. On every ground, therefore, you must admit that there exists elsewhere other congeries of matter similar to this one which the ether clasps in ardent embrace.[39]

Thus, there can be no doubt that Lucretius has in mind a multiverse structure. This can be no more evident than when Lucretius refers to the atoms "outside" the world at the outset of the passage. Those atoms exist in a place beyond the bounds of the universe, and Lucretius explicitly describes them as being constitutive of other miniverses.

The other miniverses exist contemporaneously with the universe, since Lucretius describes the other atoms as actively comprising the other miniverses; this is confirmed when Lucretius claims that it is not the case that they *are accomplishing* nothing. This provides a clue that affirms the

---

[37] One such difference involves free will: Democritus denied it, while Epicurus (and hence Lucretius) accepted it. See Lucretius (1951), p. 12 for details.

[38] The argumentative structure leading to Lucretius's multiverse will be examined in detail in Chapter 6. Lucretius does not explicitly number the atoms infinite in *De Rerum Natura*, but he consistently hints at this assumption, as on p. 91 of Lucretius (1951). Most likely, Lucretius adopts the explicit statement of his predecessor Epicurus in this respect. See Dick (1982), chapter 1 for discussion.

[39] Lucretius (1951), p. 91. Emphasis in original.

core delineator in ancient multiverse thought: the atomists espouse a multiverse for which the miniverses coexist, whereas many of the other ancient thinkers believe that the miniverses exist in temporal succession.

3
Modern Multiverse Models

With the danger of lost texts chiefly restricted to the class of ancient multiverse writers, the modern era offers a more definitive class of multiverse writings. Because these works are (predominantly) complete and unquestionably directly attributable to their authors, nearly all of the guesswork and historical theorizing present in the depiction of the ancient era is eliminated from a similar depiction of the modern era. Thus, while this portion of the multiverse tradition admits of more reliable accounts, it thereby also permits shorter, more concentrated synopses of those who play roles.

The influence of Copernicus on the thinkers of this era needs no explication. Indeed, the thoughts of most of those who qualify as part of the multiverse tradition from this era were spurred to theorizing by Copernicus's work.

As with the catalogue of the ancients, the purpose here consists in presenting a clear rendition—with supporting passages where available—of the thinker's multiverse model. The combined set of historical multiverse models generated by the ancient and modern writers will then be the fuel for creating the classification scheme that will be presented in Chapter 4.

3.1 Nicolas Cusanus (1401-1464)

Though Cusanus could not have partaken in the Copernican Revolution proper, he leaves strong evidence that he would have if he could have. He asserts straightforwardly in his *Of Learned Ignorance* (1440) that

> The earth, which cannot be the centre, must in some way be in motion; in fact, its movement even must be such that it could be infinitely less. Just as the earth is not the centre of the world, so the circumference of the world is not the sphere of the fixed stars, despite the fact that by comparison the earth seems nearer the centre and heaven nearer the circumference.[1]

[1] Cusanus (1954), p. 108.

This comes over a century before Copernicus's publication. Though Cusanus essentially asserts the result that vaulted Copernicus to a place among the scientific greats, Cusanus relinquishes precedence because his result is derived from somewhat mystical premises involving his interpretations of unity and infinity.[2]

Nevertheless, in setting the result—the movement of the earth—in place, Cusanus joins the multiverse tradition. Though we lack *direct* language from Cusanus that portrays a multiverse, as was the case with the writings of the ancients, enough can be inferred from what we do have to include him in the tradition. Furthermore, his work was influential to subsequent multiverse thinkers.

The following two passages demonstrate Cusanus's influence on the multiverse tradition. The first is from Cusanus in his attempt to demonstrate that Earth is not the center of the universe (and, hence, that it has motion within an infinite universe):

> Suppose one person were on the earth and under the arctic pole and that another were on the arctic pole; to him on the earth the pole would seem at the zenith, whereas to the person on the pole the centre would appear at the zenith. And just as the antipodes have the heavens above them as we have, so the earth would appear at the zenith to those on both poles; and no matter where a person were he would believe he was at the centre. Take, then, all these various images you have formed and merge them into one, so that the centre becomes the zenith and vice versa; and your intellect, which is aided so much by the ignorance that is learning, then sees the impossibility of comprehending the world, its movement and form, for it will appear as a wheel in a wheel, a sphere in a sphere without a centre or circumference anywhere, as has been said.[3]

The second passage comes from the work of Giordano Bruno:

> Thus we on earth say that the earth is the centre; all philosophers ancient and modern of whatever sect will proclaim without prejudice to their own principles that here is indeed the centre; just as we say that we are as it were at the centre of that [universally] equidistant circle which is the great horizon and the limit of our own encircling ethereal region, so without doubt those who inhabit the moon believe themselves to be at the centre [of a great horizon] that encircleth this earth, the sun and the other stars, and that is the boundary of the radii of their own horizon. Thus the earth no more than any other world is at the centre; and no points constitute definite determined poles of space for our earth, just as she herself is not a definite and determined pole to any other point of the ether, or of the world space; and the same is true of all other bodies. From various points of view these may all be

[2] Further investigation of Cusanus's argumentation about unity and infinity would take us too far afield; for details see the introduction by Hawkins (Cusanus (1954), pp. ix-xxviii), pages 54-59 of Singer (1950), and Cusanus's work itself (Cusanus (1954)).

[3] Cusanus (1954), p. 110.

> regarded either as centres, or as points on the circumference, as poles, or zeniths and so forth. Thus the earth is not in the centre of the universe; it is central only to our own surrounding space.[4]

The similarities between the passages are noteworthy, and this is no coincidence.[5] While the two passages do not directly contribute to either author's multiverse stance, it is a small step from here to the multiverse conclusion. Both Cusanus and Bruno invoke infinite space as a means of establishing the claim that each position in space offers the appearance of being the center of the universe.[6] (More properly, Bruno borrows this line of reasoning from Cusanus, which is what the inclusion of these two passages is intended to demonstrate.) As can be discerned, Cusanus's argument for the infinite size of the universe deeply influences Bruno to the point that he adopts the same premise. The small step to the multiverse involves adding a premise that modifies Aristotelian physics; in this way, Bruno verbalizes explicitly the multiverse framework that lies hidden on the fringes of Cusanus's thought.[7]

Though Cusanus offers little direct multiverse theorizing, he does address some of the tangential pieces to multiverse theorizing, such as typicality assumptions, that are crucially important for the present study. Those passages appear, for example, in *Of Learned Ignorance* in chapters XI and XII of the Second Book. Cusanus's work thus has relevance to the present study beyond his direct influence on Bruno and others in the tradition.

3.2 Marcellus Palingenius (c.1500-1551)

The work of Palingenius initiates the development in earnest of the multiverse concept in the modern era. The effects of peripheral factors—such as the physical theory to which he subscribes–

[4] Bruno (1950), p. 280.

[5] I do not intend to imply that the influence of Cusanus on Bruno is a novel suggestion; Bruno himself praises Cusanus in the introductory epistle to *On the Infinite Universe and Worlds*. Instead, the example is included merely to make that influence tangible from the writers themselves concerning a subject (the infinite size of the universe) that is crucial for the development of the multiverse thought of Bruno and those who follow.

[6] The claims made by Bruno and Cusanus amount to proposals that the cosmos is isotropic. A case could be made that both thinkers theorize in accordance with a forerunner of the Cosmological Principle, since both likewise maintain that infinite space is approximately uniformly filled with "worlds" that are similar in nature to each other (thereby fulfilling the "homogeneous at large scales" component of the Cosmological Principle).

[7] Further elucidation of Bruno's argument will appear in Chapter 6, where Bruno's argument from the implication of his assumed theory is displayed in full.

on Palingenius's theorizing are evident. As was the case with the ancients, however, the task at hand presently is to take careful note of Palingenius's multiverse; the contextual components will be addressed in the following chapters.

Palingenius lies at the nexus of the incumbent Aristotelian cosmology and the coming Copernican revolution. Reading like a Renaissance-era *Theogony,* his *The Zodiake of Life* explains all aspects of life, from emotions and politics to physics and astronomy. It is in his coverage of the latter topics that we encounter the first rough rendition of a multiverse design that is to appear repeatedly during the modern period. Palingenius postulates that within a single large space, the stars are not fixed in place (as his predecessors would maintain), but rather, they float free, with each inhabited with its own type of being. Each of the stars differs in size and composition, and correspondingly the inhabitants likewise vary in composition.[8]

> For creatures doth the Skies containe, and every Star beside
> Be heavenly towns and seats of saints, where Kings and Commons bide,
> But perfect Kings and people ere, all things are perfect there:
> Not shapes and shadows vaine of things, (as we have present here)[9]

The earliest version of *The Zodiake of Life* appeared in 1531, though many editions followed through 1588.[10] This gives Palingenius precedence over the several similarly constructed multiverse models that would follow, each of which employs a similar feature whereby the stars play the role of the miniverses in the multiverse. For this reason, Palingenius holds a noteworthy place in the multiverse tradition.

3.3 William Gilbert (1544-1603)

One can begin to piece together Gilbert's multiverse through studying Book VI of his *De Magnete*. Though the work is best known as the pioneering treatise on magnetism, its final book puts some of the groundwork in place for Gilbert's cosmology. (That cosmology comes to fruition in his later work, *De Mundo*.) In *De Magnete*, Gilbert vehemently argues against the incumbent notion

[8] See Palingenius (1588), pp. 212-214 for his discussion about the composition of the stars.
[9] Palingenius (1588), p. 218. Note that it is not readily apparent whether Palingenius invokes the Typicality assumption or the Atypicality assumption, though it is evident that he makes assumptions about what lies in the other miniverses.
[10] See Kelly (1965), p. 102.

of a *primum mobile*, and in so doing he replaces it with a multiverse.[11] The elimination of the *primum mobile* enables Gilbert to dispatch the companion claim that there exists a single "system" or a single "universe." That separate miniverses are involved is evident in the following chain of passages:

> Thus, inasmuch as the sun itself is the mover and inciter of the universe, the other planets that are situate within the sphere of his forces, being impelled and set into motion, do also with their own forces determine their own courses and revolve in their own periods…But as between the moon and the earth, it is more reasonable to believe that they are in agreement, because, being neighboring bodies, they are very like in nature and in substance, and because the moon has a more manifest effect on the earth than have any of the other stars, except the sun.[12]

Gilbert here hints at the notion of influence exhibited between bodies, and he further hints that the influence a body exhibits has limited reach, a limitation which defines a "sphere" for the influence. He made this notion explicit a few pages earlier in his work:

> This is the case in all primary bodies—the sun, moon, earth,—the parts betaking themselves to their origin and founts, whereunto they are attached with the same appetence with which what we call heavy bodies are attached to the earth. Thus lunar bodies tend to the moon, solar to the sun, within the respective spheres of their effluences.[13]

Taken together, the passages provide the foundation for miniverses as "globes," which are comprised of groupings of bodies, including a star and its nearby planets.[14]

That there exist regions devoid of influence on each other—a necessity for miniverses within a multiverse—is likewise made apparent in nascent form in *De Magnete*. Gilbert writes:

> Hence, that these [stars] are many, and that they never can be taken in by the eye, we may well believe. What, then, is the inconceivably great space between us and these remotest fixed stars?...How far away from earth are those the remotest of stars: they are beyond the reach of eye, or man's devices, or man's thought…It is evident, therefore, that all the heavenly bodies, being, as it were, set down in their

[11] For Gilbert's arguments against the *primum mobile*, see, for example, pp. 320-327 of Gilbert (1958). He has several separate arguments against it, some of which include: 1) Observation shows that further-out objects (from the sun) take increasingly longer times to complete their orbits, meaning that the supposed *primum mobile* should be the slowest of all. Yet, if it exists, it completes its motion in just 24 hours. 2) All observed objects move from west to east in the sky, whereas the *primum mobile* inexplicably would move from east to west. 3) The *primum mobile* has no discernible cause for its motion, counter to any well-established doctrine.

[12] Gilbert (1958), pp. 344-345.

[13] Gilbert (1958), p. 340.

[14] It is not straightforwardly clear whether Gilbert definitively determines whether a globe can contain more than one star. The initial passage seems to indicate that at least some stars besides the sun have an effect (even if negligible) on the earth, which would include them within the same globe that houses the earth and the sun. Nevertheless, separate non-interacting regions are present in Gilbert's cosmology, as will be made clear imminently.

> destined places, in them are conglobed whatever elements bear to their own centres, and around them are assembled all their parts.[15]

These pieces, taken together, set the stage for *De Mundo*.

De Mundo was not published until 1651, well after Gilbert's death. In fact, it was not complete when he died, and reasonable assumptions lead to the conclusion that Gilbert worked on the treatise, bit by bit, from the 1550s until his death in 1603.[16] This is significant because the multiverse that Gilbert constructs is remarkably similar in style to that of his contemporary, Giordano Bruno, who published his multiverse works in the latter part of the sixteenth century.[17] This suggests that there was influence one way or the other, and several writers of Gilbert's time associate Gilbert and Gilbert's thought with Bruno and Bruno's thought.[18] Nevertheless, Gilbert does not make explicit mention of Bruno in *De Mundo*.[19]

Fuller details of Gilbert's multiverse emerge in *De Mundo*. The miniverses—the sets of "globes"—are completely self-contained, floating within a void. Though it is not clear whether Gilbert favors a void that is infinite, there is no doubt that he maintains that it is very large, and this permits Gilbert to postulate that there exist globes beyond the visible horizon.[20] This existence of unobservable globes, coupled with the assumption that anything leaving a globe will necessarily be attracted back to it, generates for Gilbert the multiverse scenario previously foreshadowed in *De Magnete*.[21] The pieces, introduced in *De Magnete*, are synthesized into a system in *De Mundo* that bears the multiverse mark.

Gilbert's work (or perhaps more accurately, the work which resulted from the association of Gilbert and his colleagues in England during the latter portion of the sixteenth century) initiates a multiverse trend. Characteristic of this trend is an avowed reference to the influence of Copernicus that leads to the postulation of many coexistent "worlds." These miniverses are typically associated with the stars, though subtle differences (such as Gilbert's "globe" classification) set them apart from each other.

---

[15] Gilbert (1958), pp. 319-320.
[16] See Kelly (1965), pp. 12-24.
[17] For details on Bruno's multiverse, see his section below.
[18] See, for example, Singer (1950), pp. 66-68, 182, and 189-191 for several examples.
[19] Kelly (1965), p. 100. Kelly's work is not a translation of *De Mundo*, but it is the most complete synopsis of the work. The *De Mundo* itself can be found only in its original Latin version. What follows is derived from Kelly's analysis.
[20] Kelly (1965), p. 101. There, she cites pp. 48-49, 113-114, 192-193, and 202 of Gilbert's *De Mundo*.
[21] See Kelly (1965), pp. 25-44 for details about Gilbert's cosmology.

3.4 Giordano Bruno (1548-1600)

Bruno is the first in the modern era to aggressively postulate the existence of the multiverse to the point of notoriety. Because of this, in the rare case that the history of multiverse thought is discussed, Bruno is often misattributed with being among the forerunners.[22] (As the preceding has demonstrated, Bruno is predated not only by some multiverse theorists of his own era, but also by a fairly sizeable contingent in the ancient era.) Nevertheless, Bruno's demotion from precedence does not diminish his role in the multiverse tradition.

Bruno runs counter to many of the long-standing doctrines of Aristotelianism.[23] Within his modified physical system, Bruno generates a multiverse that immediately removes the sun from the center of the Universe—from the place to which Copernicus had just recently moved it—and places it within an infinite space filled with other "worlds":

> We have but one single heaven, a single space through which our own star in which we reside, and all other stars perform each their own circuits and courses; these are the infinite worlds, the innumerable stars; this is the infinite space, the heaven comprehending all, traversed by all…Here then is the true nature of the worlds and of the heaven. The heaven is such as we see it around our own globe which is, like the other globes, a luminous and excellent star. The worlds are those whose brilliant shining surfaces are distinctly visible to us, and they are placed at certain intervals one from another.[24]

Bruno thus constructs a multiverse whose set of miniverses includes some which are partially accessible in terms of their observability (the visible stars). The rest, which include the infinite remaining globes floating outside of the horizon visible in the night sky, are no less real than their gazed-upon counterparts.

As noted in the preceding discussion of Gilbert, it is no accident that both Bruno and Gilbert refer to "globes" as their miniverse-equivalents. Gilbert is one of many whose path in the multiverse tradition intersects with that of Bruno. The previously mentioned influences of Epicurus and Cusanus, as well as the influence of other characters already encountered, are pervasive throughout Bruno's writings. For example, short referential passages (such as the following two) are peppered throughout Bruno's works:

---

[22] See footnote 1 of Chapter 2 for an example.

[23] The argumentative import of modifications made by Bruno to certain aspects of the Aristotelian physics will play an important role in Chapter 6.

[24] Bruno (1950), p. 370-371.

> Now this distinction [separation] of bodies in the ethereal region was known to Heraclitus, Democritus, Epicurus, Pythagoras, Parmenides, Melissus, as those fragments which we possess make it manifest to us; thus, it is clear that they knew of an infinite space, infinite region, infinite forest [mass], infinite capacity of innumerable worlds, and the like.[25]
>
> To this argument we have amply replied, and we declare that there are an infinity of earths, an infinity of suns, and an infinite ether—or, as Democritus and Epicurus have it, an infinite Plenum and infinite Vaccuum, the one placed within the other.[26]

Though Bruno could not have actually labeled himself a "multiverse theorist," he was eminently aware that there *was* a tradition and he was aware that he was part of it. On these grounds, it is ironic that he is (contemporarily) often mistaken for the originator of ideas akin to the multiverse, since he is one of the exceedingly few writers in the tradition to make repetitive note of the tradition itself that leads to the creation of his work.

3.5 Henry More (1614-1687)

More's contribution to the tradition lies almost entirely in the domain of argumentation for the multiverse, so his work will play a larger role in Chapter 6. Even still, his pending importance makes necessary a reference to him here, so a brief description of his Brunoian-style multiverse is in order.

In most respects unremarkable (due to the heavy influence of the atomists upon him), More's multiverse consists of a large (perhaps infinite) space populated with miniverses taking the form of congregated matter in solar-system-like arrangements. His description:

> I will not say our world is infinite,
> But that infinitie of worlds there be
> …
> No serious man will count a reason slight
> To prove them both, both fixed suns and starres
> And Centres all of severall worlds by right,
> For right it is that none a sun debarre
> Of Planets which his just and due retinue are.
> …
> Wherefore at once from all eternitie
> The infinite number of these Worlds He made,
> And will conserve to all infinitie,

[25] Bruno (1975), p. 148.
[26] Bruno (1950), p. 283-284.

And still drive on their ever-moving trade,
And steddy hold what ever must be staid,
Ne must one mite be minish'd of the summe,
Ne must the smallest atom ever fade,
But still remain though it may change its room;
This truth abideth strong from everlasting doom.[27]

The first bit of the passage is potentially misleading. More is not claiming that space is finite, which one might infer from his claim that he "will not say that our world is infinite." Instead, context reveals More's intended claim. He is grappling with the atomistic assumption (which he embraces) that the number of atoms is infinite (thus generating infinite matter). This leaves two possibilities: a single infinite world or an infinite number of finite worlds. More, as the passage indicates, opts for the latter. So *our* world—the universe, as properly described in the vernacular of this project—is finite. The same is true of the other worlds (miniverses). Furthermore, there are an infinite number of miniverses. Thus, when interpreted properly, these simple lines are a direct affirmation of More's multiverse stance.

The remainder of the passage fills in most of the details of More's multiverse. One item of note is More's assertion that the miniverses themselves exist eternally. Most atomists before and contemporary with More maintain that the atoms themselves are eternal, but that the miniverses coalesce and decay as time marches forward. More, as the passage describes, claims that not only the atoms, but also the miniverses themselves, remain established eternally.

3.6 Margaret Cavendish (1623-1673)

Cavendish is remarkable for two reasons. First, she possesses the precedence for an archetype of multiverse that hitherto has not appeared in the tradition. Her *Poems and Fancies* of 1653 exhibits a procession of thought which begins with consideration of the possibility of a multiverse and results, by work's end, in speculation of the novel multiverse model. Second, in so developing the implications of her multiverse thought, she becomes the first to contemplate a multi-faceted multiverse.

Rich with physical theory written in verse, Cavendish's intersection with the multiverse concept begins with a footnote. In the work proper, Cavendish remarks that "In Infinities no Center

[27] More (1646), pp. 6-18.

can be laid, / But if the World has Limits, Center's made."[28] The footnote to this reads: "Unlesse there be Infinities of Worlds; then there may be infinities of Centers, although not a Center in Infinities."[29]

The implications of the footnote are further developed as the work unfolds. The next excursion into multiverse thought comes with Cavendish's development of her cosmological system:

> If Infinities of Worlds, they must be plac'd
> At such a distance, as between lies waste.
> If they were joined close, moving about,
> By justling they would push each other out.
> And if they swim in Aire, as Fishes do
> In Water, they would meet as they did go.
> But if the Aire each World doth inclose
> Them all about, then like to Water flowes;
> Keeping them equall, and in order right.
> That as they move, shall not each other strike.
> Or like to water wheels by water turn'd,
> So Aire round about those Worlds do run:
> And by that Motion they do turne about,
> No further then that Motions strength runs out.
> Like to a Bowle, which will no further go,
> But runs according as that strength do throw.
> Thus like as Bowles, the Worlds do turne, and run,
> But still the Jacke, and Center is the Sun.[30]

Not without precedent—Cavendish was well-educated in the physics and philosophy of her time—Cavendish here describes the multiverse arrangement espoused by Palingenius, Gilbert, Bruno, and More.[31] There are subtle differences with the earlier thinkers, such as her retention of the sun at the center of everything.[32]

It is her further pursuance of the possibilities offered by the multiverse that sets Cavendish apart from her predecessors. She puts it thus:

> Then probably may Men, and Women small,
> Live in the World which wee know not at all;
> May build them Houses, severall things may make,
> Have Orchards, Gardens, where they pleasure take;
> And Birds which sing, and Cattell in the Field,

[28] Cavendish (1972), p. 29.
[29] Cavendish (1972), p. 29.
[30] Cavendish (1972), p. 30.
[31] See Lilley's introduction in Cavendish (1994) for details concerning Cavendish's biography, including her education.
[32] This likely indicates the strong influence of Copernicus upon Cavendish's thought, yet again emphasizing her education in the field.

May plow, and sow, and there small Corne may yield;
And common-wealths may have, and Kings to Reigne,
Wars, Battells have, and one another slaine:
And all without our hearing, or our sight,
Nor yet in any of our Senses light.
And other Stars, and Moones, and Suns may be,
Which our dull Eyes shall never come to see.[33]

This concept (before Cavendish) is novel in the multiverse tradition: she separates the miniverses by scale, enclosing one miniverse (subjectively complete and properly proportioned from within) fully inside another.

In a passage entitled "A World in an Eare-Ring," Cavendish offers the culmination of her multiverse thought, which involves an explicit hypothetical example:

An Eare-ring round may well a Zodiake bee,
Wherein a Sun goeth round, and we not see.
And Planets seven about that sun may move,
And Hee stand still, as some wise men would prove.
And fixed Stars, like twinkling Diamonds, plac'd
About this Eare-ring, which a World is vast.
…
There nipping Frosts may be, and Winter cold,
Yet never on the Ladies Eare take hold.
And Lightnings, Thunder, and great Winds may blow
Within this Eare-ring, yet the Eare not know.
There Seas may ebb, and flow, where Fishes swim,
And Islands be, where Spices grow therein.[34]

The passage extends to include much more extensive description of the miniverse potentially contained within the earring.

As noteworthy as Cavendish's description of the multiverse model may be, perhaps of even greater importance is the passage (entitled "Severall Worlds in severall Circles") that immediately follows the earring example. In it, Cavendish reasserts the Brunoian-style multiverse:

There may be many Worlds like Circles round,
In after Ages more Worlds may be found.
If we into each Circle can but slip,
By Art of Navigation in a Ship;
This World compar'd to some, may be but small:
No doubt but Nature made degrees of all.
If so, then Drake had never gone so quick
About the Largest Circle in one Ship.

[33] Cavendish (1972), p. 44.
[34] Cavendish (1972), p. 45.

For some may be so big, as none can swim,
Had they the life of old Methusalem.
Or had they lives to number with each day,
They would want time to compasse halfe the way.
But if that Drake had liv'd in Venus Star,
His Journey shorter might have been by farre.[35]

In closing her writing about the multiverse this way, Cavendish establishes a two-tiered multiverse: the stars and planets represent worlds of their own, scattered throughout space as described by both the ancient atomists and Cavendish's contemporaries, but she postulates a second domain of inaccessible miniverses embedded within the matter that makes up the first-tier multiverse (as exemplified by the earring). With respect to contemplation of such a multi-faceted multiverse, Cavendish stands as the first to do so. The negative conceptual ramifications of doing so are not easily dispatched.

For example, it is not evident that there can be a "proper" way to conceptualize Cavendish's multiverse.[36] It could be imagined as a vast expanse of space that contains countless miniverses, each of which contain small scaled miniverses within its matter. (This would correlate to first imagining Brunoian-style miniverses and then imagining the earring-style miniverses contained therein.) Alternatively, Cavendish's multiverse could be imagined as a single chain-of-scale, with each miniverse in the chain contained within the matter of the previous miniverse. Each of the scaled miniverses would then contain a vast expanse of space that contains countless miniverses. (This would correlate to first imagining the earring-style miniverses of scale contained one within the other and then imagining Brunoian-style miniverses within each.)

The conceptual difficulty here is apparent, and it is a genuine hurdle that obscures clarity within multiverse theory. Additionally, matters will get worse before they improve, as Cavendish's initial foray into the tiered multiverse does not involve mixing typicality assumptions.[37]

[35] Cavendish (1972), p. 46.
[36] A structured method for accounting for multiverse models such as Cavendish's will be presented in Chapter 4.
[37] The first instance that includes a mixture of typicality assumptions arrives with the thought of Huygens.

3.7 Blaise Pascal (1623-1662)

Passage 72 from Pascal's *Pensées* identifies him as of like mind with Cavendish concerning her multiverse of scale.[38] This much is made clear in the following passage, after speaking of the minute detail of a mite's anatomy:

> Perhaps he will think that here is the smallest point in nature. I will let him see therein a new abyss. I will paint for him not only the visible universe, but all that he can conceive of nature's immensity in the womb of this abridged atom. Let him see therein an infinity of universes, each of which has its firmament, its planets, its earth, in the same proportion as in the visible world; in each earth animals, and in the last mites, in which he will find again all that the first had, finding still in these others the same thing without end and without cessation.[39]

This passage is oft-referenced in discussions of the development of the concept of space.[40] However, of perhaps greater importance—given the already-extant proposal by Cavendish of the concept of miniverses embedded within our universe—is Pascal's material that precedes the above passage.

Pascal prefaces the mite example with a very important addition to the theory. The addition is plainly evident:

> Let man then contemplate the whole of nature in her full and grand majesty, and turn his vision from the low objects which surround him. Let him gaze on that brilliant light, set like an eternal lamp to illuminate the universe; let the earth appear to him a point in comparison with the vast circle described by the sun; and let him wonder at the fact that this vast circle is itself but a very fine point in comparison with that described by the stars in their revolution round the firmament. But if our view be arrested there, let our imagination pass beyond; it will sooner exhaust the power of conception than nature that of supplying material for conception. The whole visible world is only an imperceptible atom in the ample bosom of nature. No idea approaches it. We may enlarge our conceptions beyond all imaginable space; we only produce atoms in comparison with the reality of things.[41]

Pascal thus extends the scaling of the spatial dimension outward in addition to inward, which differentiates his otherwise-similar multiverse postulation from that proposed by Cavendish.

---

[38] Though born in the same year, Cavendish outlived Pascal by over a decade, and she apparently retains precedence with respect to the "scaled" multiverse concept. Her *Poems and Fancies* from 1653 predates Pascal's *Pensées*, the "plan of [which]…formed itself about 1660," according to Eliot's introduction to the work (Pascal (1958), p. xi).
[39] Pascal (1958), p. 17.
[40] See, for example, Gale (1998), p. 196 and Čapek (1976), p. 89.
[41] Pascal (1958), p. 16.

Implications of this operation with respect to Pascal's apparent adoption of the Typicality assumption have not gone unnoticed: Čapek takes Pascal's passage to indicate that Pascal subscribed to "*the unity of nature in space*; nature is basically the same everywhere and on any level of magnitude."[42]

3.8 Christiaan Huygens (1629-1695)

Huygens presents a fascinating case. Considerable attention will be paid (in Chapter 7) to typicality assumptions and their emergence in the work of thinkers well before Huygens. But to postpone their discussion in the case of Huygens would be to misconstrue his chief contribution to the multiverse tradition. The very title of his work— *Cosmotheoros: Conjectures Concerning the Planetary Worlds and Their Inhabitants*—invokes attention for the student of typicality assumptions. In it, Huygens carries Bruno's torch concerning the nature of the stars; the stars are all worlds, each with a sun, each sun with a set of planets. That Huygens adopts this stance from Bruno is not in question: he references Bruno (and Cusanus, among others) early in the treatise, and he further reinforces the influence throughout the work, to the point that even in the final pages, Huygens continues to hail Bruno.[43]

The bulk of the work is dedicated to theorizing about those living on the planets and moons within the solar system. Book I, which comprises two thirds of the 219-page work, meticulously undertakes a comparison between all facets of life on Earth and those same facets of life for the "planetarians," the term Huygens uses to refer to the inhabitants of the other planets. This reliance on the system popularized by Bruno lends itself, at first glance, to the Typicality assumption. And, for the most part, Huygens obliges:

> But I must give my vote, with all the greatest philosophers of our age, to have the sun of the same nature with the fix'd stars. And this will give us a greater idea of the world, than all those other opinions. For then why may not every one of these stars or suns have as great a retinue as our sun, of planets, with their moons, to wait upon them?[44]

[42] Čapek (1976), p. xxv. Emphasis in original.
[43] See, for example, the reference to Bruno on p. 3 of Huygens (1757), and the further reference to Bruno's system in the passage that is provided below.
[44] Huygens (1757), p. 202.

Huygens likewise (with Bruno) extends to each of these systems observers on the planets orbiting the stars. Furthermore, like Bruno, Huygens accepts both that space is infinite, and that there are stars that we have no access to, even visually. Thus Huygens appears to have a multiverse constructed of miniverses represented by stars and orbiting planets exactly in the vein of Bruno, and he also appears to follow Bruno in adopting the Typicality assumption to cover those miniverses.

However, by the time one reaches the end of the work, it is quite apparent that globally, Huygens shies away from taking the Typicality assumption. In fact, though he accepts infinite space, he is reluctant to populate it in the manner Bruno does. Huygens writes:

> Some of the antients, and Jordanus Brunus carried it further, in declaring the number [of stars] infinite: he would perswade us that he has prov'd it by many arguments, tho' in my opinion they are none of them conclusive. Not that I think the contrary can ever be made out. Indeed it seems to me certain, that the universe is infinitely extended; but what God has been pleas'd to place beyond the region of the stars, is as much above our knowledge, as it is our habitation.
>
> Or what if beyond such a determinate space he has left an infinite vacuum; to show, how inconsiderable all that he has made is, to what his power could, had he so pleas'd, have produc'd? but I am falling, before I am aware, into that intricate dispute of infinity: therefore I shall wave this, and not, as soon as I am free of one, take upon me another difficult task.[45]

Huygens eschews the Typicality assumption by declining to assent to the notion that what he observes—or even all that he theorizes about within *Cosmotheoros*—is representative of what lies in the far-flung reaches of his infinite space.

This is a noteworthy development. By rejecting the Typicality assumption, Huygens does not thereby adopt the Atypicality assumption: in fact, he makes clear in the passage above that he does not want to commit himself to either assumption. Rather, he stands firm in merely asserting his ignorance. By doing so, Huygens establishes himself as the founding member of an exceedingly small subset of all multiverse theorists, namely those that refrain from asserting a typicality assumption.[46] In effect, Huygens has closed the possibility space: one may either espouse the Typicality assumption, the Atypicality assumption, or assert Ignorance.[47]

[45] Huygens (1757), p. 211-212.

[46] This minority stance, as will be discussed in Chapter 9, has received a philosophical resurgence lately with the work of John Norton.

[47] I have capitalized "Ignorance" as I do "Typicality" or "Atypicality" to convey the explicit assent to the assumption of ignorance. Recall that "typicality assumption" (lowercase) refers generically to either the Typicality

To complicate matters, Huygens does not cease discussion upon adopting the Ignorance assumption. Instead, he provides further theoretical detail about the miniverses made up of the stars and their associated planets. Like Descartes, Huygens implements vortices as the mechanism that separates vast expanses of space. Unlike Descartes, the construct put forth by Huygens satisfies the parameters set forth for qualification as a multiverse:

> I must differ from him [Descartes] too in the bigness of the vortices, for I cannot allow them to be so large as he would make them. I would have them dispers'd all about one immense space, like so many little whirlpools of water, that one makes by the stirring of a stick in any large pond or river, a great way distant from one another. And as their motions do not at all intermix or communicate with one another; so in my opinion must the vortices of stars be plac'd as not to hinder one another's free circumrotations.
>
> So that we may be secure, and never fear that they will swallow up or destroy one another; for that was a mere fancy of Cartes's, when he was showing how a fix'd star or sun might be turned into a planet.[48]

It is clear that Huygens has postulated a multiverse of the style espoused by Bruno out to a certain (unspecified) distance. Within that expanse of space, he claims that the universe is typical of what is to be found amongst the other miniverses. Thus he adopts the Typicality assumption. However, he also takes pains to note that he makes no claims at all about what lies beyond that (unspecified) distance. Thus he adopts the Ignorance assumption.

Huygens thereby creates a quandary of significant importance. With Cavendish, we witnessed the conceptual difficulty that supervened upon the construction of a multiverse whose miniverses were related to each other in two different ways (separated in space from each other and scaled within each other). In the case of Huygens, we see the conceptual difficulty that supervenes upon the inclusion of conflicting typicality assumptions within the same multiverse construct. The issue is one that necessitates elucidation of the typicality assumptions themselves.[49]

---

or the Atypicality assumption, whereas the capitalized version refers specifically to the assumption that is capitalized.

[48] Huygens (1757), p. 217. Bracketed addition inserted for clarity.

[49] The issue, which resides near the core of this project, will receive continual treatment as we proceed, especially in Chapters 7 and 8.

3.9 David Hume (1711-1776)

Hume's multiverse proposal in *Dialogues Concerning Natural Religion* is intended as an alternative to religion that can perform the same explanatory task without the supernatural underpinnings.[50] He describes it thus:

> Instead of supposing matter infinite, as Epicurus did; let us suppose it finite. A finite number of particles is only susceptible of finite transpositions: And it must happen, in an eternal duration, that every possible order or position must be tried an infinite number of times. This world, therefore, with all its events, even the most minute, has before been produced and destroyed, and will again be produced and destroyed, and without any bounds and limitations.[51]

The direct reference to Epicurus should not go unnoticed, and there are obvious similarities here to the models proposed by some of the ancients, particularly Anaximander, Heraclitus, and Empedocles.

A key difference between the model proposed by Hume and that of Epicurus appears to be Hume's restriction to a single miniverse existing at any given time; this is detailed further in the following passage:

> All the parts of each form must have a relation to each other, and to the whole: And the whole itself must have a relation to the other parts of the universe; to the element, in which the form subsists; to the materials, with which it repairs its waste and decay; and to every other form, which is hostile or friendly. A defect in any of these particulars destroys the form; and the matter, of which it is composed, is again set loose, and is thrown into irregular motions and fermentations, till it unite itself to some other regular form. If no such form be prepared to receive it, and if there be a great quantity of this corrupted matter in the universe, the universe itself is entirely disordered; whether it be the feeble embryo of a world in its first beginnings, that is thus destroyed, or the rotten carcass of one, languishing in old age and infirmity.[52]

Whereas Epicurus conceptualized atoms throughout infinite space collecting into countless miniverses and eventually dispersing, Hume imagines atoms within a confined finite space collecting and dispersing throughout time, creating a multiverse whose miniverses are strung out in the temporal dimension. Hume's reference to the "whole" in this context denotes the multiverse itself; it is composed of the successive "worlds," which play the role of miniverses. Indeed, the

[50] The employment of the multiverse for the purpose of explanation will receive special attention in Chapter 6. Hume's argumentation to this effect will be inspected in detail at that time.
[51] Hume (1947), p. 182.
[52] Hume (1947), pp. 183-184.

focus on the relationship between the whole and the parts—between the multiverse and the miniverses—is an emphasis of thought that was heavily portrayed in the thought of Empedocles, as noted in Chapter 2.

3.10 Thomas Wright (1711-1786)

Wright may be the member within the multiverse tradition who most explicitly recognizes the tradition. He not only recognizes the work of those within his era (such as Bruno and Huygens), but he also acknowledges the work of ancients, including Empedocles and Heraclitus, both of whom were introduced in Chapter 2.[53] Furthermore, Wright advances arguments of two different types for the existence of his multiverse model and he subsequently generates argumentation for the Typicality assumption.

As with the preceding authors, however, the purpose for the present will be restricted to providing sufficient evidence to establish that Wright advocates a multiverse. This is not difficult, as his 1750 work (*An Original Theory or New Hypothesis of the Universe*) is full of argumentation that qualifies him. Like many of his era, Wright advances a multiverse structure that closely follows, but differs slightly from, Bruno's thought. This is immediately evident from the table of contents, where Wright summarizes the Sixth and Seventh Letters of his work, respectively, as "Of General Motion amongst the Stars, the Plurality of Systems, and Innumerability of Worlds" and "The Hypothesis, or Theory, fully explained and demonstrated, proving the sidereal Creation to be finite."[54] He uses Bruno's own reference to "innumerable worlds," but he opposes Bruno's conception of infinite space.

The likeness to Bruno's multiverse emerges in several places, exemplified by Wright's characterization that since

> The Stars are all of the same Kind, I think it may be agreed, that what we evince of any one may be allowed to be true of any other, and consequently of all the rest…The Sun we have justly reduced to the State of a Star, why then in Reason should he have his attendant Planets round him, more than any of the rest, his

[53] Within his 1750 work, see, for instance, p. 3 for acknowledgement of Bruno, p. 5 for recognition of Huygens, and p. 30 for references to Empedocles and Heraclitus.
[54] Wright (1750), "Contents."

> undoubted Equals? No Shadow even of a Reason can be given for such an Absurdity.[55]

Wright's multiverse includes the stars and their corresponding planetary systems in the role of miniverses, which approach more closely the contemporary notion of miniverses within the multiverse when he describes them as follows:

> The Laws of any one in no wise shall interfere, disturb, or interrupt the Principles of another; this Comet, which we can easily prove belong'd to our own sun, we may well imagine came not near any other; and tho' at that vast Distance from the solar Body, yet still there must have remain'd a Space sufficient to divide or separate the sensible activity of neighboring Systems, that they may not rush upon each other.[56]

Thus we see Wright provide clear and explicit articulation of the principle that miniverses are separate and inaccessible to each other, and with it sure evidence that Wright's structure is a multiverse.

The brevity here in portraying Wright's thought is merely a placeholder for discussion of the arguments for the multiverse and typicality assumptions that he puts forth; those will receive deeper attention in Chapter 6.

3.11 Roger Boscovich (1711-1787)

Boscovich is an essential piece of the multiverse tradition owing to two musings. Interestingly, the two thoughts appear to contradict each other; in one, Boscovich claims that conception of a multiverse can be undertaken with little effort, and in the other he claims that such conception is extremely difficult. Though resolving the apparent contradiction is not of concern here, the inclusion of Boscovich's passages most certainly is.[57]

The first (and earlier) passage appears in 1755. In it, Boscovich describes a multiverse akin to that described in Cavendish's earring example and Pascal's mite example:

---

[55] Wright (1750), p. 33.
[56] Wright (1750), p. 70.
[57] Two means of resolving the fact that the passages appear to contradict each other are readily apparent. 1) The multiverses discussed by Boscovich in the two passages are of two different types. This becomes clearly evident in Chapter 4. 2) Boscovich changed his views in the eight years between writing the two passages. This would give ultimate precedence to the second passage in what follows, since that one was written later, and hence would (presumably) represent Boscovich's most mature viewpoint. Resolving the historical truth in this matter, of course, is beyond present purposes; both passages are equally important for the current endeavor.

> It is conceivable that in some small grain of sand which we can hardly perceive there is hidden a whole world in which there is an immense number of living beings so small that they escape not only our perception, but also the perception of those tiny living beings which we hardly observe under a microscope. Is it not possible that there be a long series of such worlds, which, with respect to one another have the same relation as our single grain of sand has to the whole world?
>
> …
>
> Whatever the truth of the matter, it really seems beyond doubt that what is for us a vanishing instant seems to be a very long time to those very tiny living beings. In this respect it occurs in those little animals something similar to what we observe in the pendulums of a shorter length whose number of oscillations is in a given time so much larger, the shorter is their length. So these very tiny living beings,…, if they pass through three or four generations in a day, regard this day as a century.[58]

The first portion of the passage depicts the essence of Cavendish's conception of miniverses embedded within the universe. The second portion, however, is decidedly novel in that it fuses the scaling of the temporal dimension to the scaling of the spatial dimension. Čapek describes this relationship by noting that "to the idea of 'the worlds within the worlds' corresponds the idea of 'histories within histories'."[59] The prominence of the multiverse constructed of scaled miniverses thus grows within the tradition as increasingly more theorists tinker with its qualities in unique ways.

The second passage of note is presented in Boscovich's *A Theory of Natural Philosophy* from 1763. It reads:

> Next, we consider the different kinds of combinations of points of space & instants of time. Any point of matter, if it exists, connects together some point of space & some instant of time; for it is bound to exist somewhere & sometime. Even if it exists alone, it always has its own mode of existence, both local & temporal; & by this fact, if any other point of matter exists, having its own modes also, it will acquire a relation of distance, both local & temporal, with respect to the first. This at least will certainly be the case, if the space belonging to all that exist, or can possibly exist, is common; so that the points of position belonging to the one coincide perfectly with those belonging to the other, each to each. But, what if there are other kinds of things, either different from those about us, or even exactly similar to ours, which have, so to speak, another infinite space, which is distant from this our infinite space by no interval either finite or infinite, but is so foreign to it, situated, so to speak, elsewhere in such a way that it has no communication with this space of ours; & thus will induce no relation of distance. The same remark can be made with regard to a time situated outside the whole of our eternity. But

[58] Boscovich (1976), p. 225. The text is translated by Čapek and Emge from Boscovich's commentary to *Philosophiae recentioribus versibus tradita a Benedicto Stay libri decem*, Vol. III, Romae 1755, pp. 421f.
[59] Čapek (1976), p. xxxvi.

> such an idea requires an intellect of the greatest power to try to grasp it; & it cannot be admitted by direct consideration, in any way, or at least with difficulty. Hence, omitting altogether such things, or the spaces & times of such things which are no concern of ours, let us consider the things that have to do with us.[60]

Boscovich here demonstrates likeness to Huygens in his reluctance to pursue his multiverse thought further. However, the few steps he takes, the strictly analytical approach he exudes in taking those steps, and perhaps most importantly, the steps he *does not* take, are significant.

In place of emphasizing the intrinsic qualities of basic bits of matter as the atomists did, Boscovich investigates the relational qualities between any two bits. Doing so prompts Boscovich to think beyond the standard methods of separating the universe from the other potential miniverses. Whereas earlier multiverse thinkers (including Boscovich himself at an earlier time) separated miniverses according to location within the same stretch of space or the same stretch of time, Boscovich conceptualizes miniverses that lie entirely outside of each other's expanse of space and time. This makes Boscovich a forerunner of multiverse theories that place miniverses in separate dimensions from each other.[61]

Though Boscovich neglects further investigation of his thoughts on the matter due to its "difficulty" to grasp, it is important to note that he does not deny the multiverse on those grounds. This removes Boscovich (by virtue of the present passage) from inclusion among the camp that opposes multiverse thought. By the same line of reasoning, this passage is telling in that Boscovich likewise does not haphazardly pursue unwarranted speculation; instead, due to the unsure footing, he refrains from going further and retreats to matters that are within his means to investigate. Boscovich's apparent decision to adopt the Ignorance assumption is an approach that, as the foregoing has shown, proves to be rare in the multiverse tradition.

3.12 Immanuel Kant (1724-1804)

Kant's cosmology is developed in his *Universal Natural History and Theory of the Heavens*. The basics of the scheme were introduced in the Prologue, so only minimal additions are necessary to

---

[60] Boscovich (1966), p. 199.

[61] One could make the case that Boscovich's earlier example (and likewise Cavendish's earring example and Pascal's mite example) likewise envisioned miniverses that were in altogether separate expanses of space, but I think instead that a more proper description of those concepts involves not *separate* expanses of space (and time), but rather *scaled* expanses of space (and time). This will receive attention in Chapter 4.

fully convey his model. Recall that Kant puts forth structured thought that closely resembles contemporary anthropic reasoning. This facilitates the emergence of typicality assumptions within his cosmology.

Concerning Kant's multiverse structure, a basic premise from the work's opening paragraph is that "the fixed stars, as so many suns, are centers of similar systems in which all may be arranged just as greatly and orderly as in ours, and that the infinite cosmic space swarms with world-edifices whose number and excellence has a relation to the inexhaustibility of their Creator."[62] This layout—reminiscent of Bruno and so many others throughout this era—is reinforced in several very similar passages.[63]

However, Kant's full cosmological structure is of deeper complexity; the star-system worlds form only a piece of it. The star-systems, scattered throughout the cosmos, are restricted in their existence to certain locations:

> It seems that this end, imposed on those worlds as well as on all things of nature, is subject to a certain law whose consideration gives to the theory a new feature of respectability. According to that law that end occurs in those cosmic bodies which are closest to the center of the universe, just as the generation and formation first started near that center; from there decay and collapse spread out into the farther distances to bury finally through a gradual collapse of motions in a single chaos all world[s] which has [have] completed its [their] period[s]. On the other hand, nature is unremittingly busy on the opposite border of the developed world in building worlds from the raw means of scattered elements and while she ages on one side beside the center, she is young on the other side and fruitful in new begetting.[64]

Whereas earlier models took the star-systems in infinite space to be miniverses, Kant postulates outwardly emanating "shells" that play the role of the miniverses. The shells, expanding further and further from the center, generate regions of order within the infinite chaos.[65]

The shells satisfy the causal disconnection clause for miniverses. There can be no traversing the bounds of a shell, according to Kant, as is made evident by the following counterfactual claim:

> If we could overstep [the boundary of] a certain sphere, we would spot there the chaos and the dispersion of elements which have according to the measure as they find themselves closer to that center, in part abandoned the raw state and are closer

[62] Kant (1981), p. 101.
[63] See, for example, p. 148-149, 183-184, and 200 of Kant (1981).
[64] Kant (1981), p. 159. Bracketed adjustments are included in Jaki's translation.
[65] Jaki notes that many have observed the obvious difficulty with Kant's account, namely locating a "center" within the infinite universe from which the shells of order can emanate.

> to the perfection of formation, whereas with [increasing] degrees of distance they are gradually lost in a complete dispersion.[66]

Thus, within a shell of order, situated as we are, we can observe other star-systems, and even systems of systems within our shell, but we cannot glimpse beyond the order into the chaos.[67]

Interestingly, these parameters detail a structure that cannot be fully described without resort to indexing the perspective of the description. From within the structure, given eons of time and a safe stationary location from which to observe, one would witness successive oscillations between ordered existence and chaotic decay; the multiverse would appear to have temporally separated miniverses. But from a position outside the structure, the miniverses would appear to take the form of the successive shells of alternating chaos and order that emanate from the center. Because of this indexical feature, Kant's model is an ideal example for the illustration of the need for additional terminological standardization within the multiverse tradition. (We previously encountered a budding version of the difficulty in Cavendish's model.) In this case, the concept of the "tier"—which will be implemented in Chapter 4—alleviates the problem.

Finally, toward the aim of unifying the tradition, it is important to note the similarity of the cosmological structure put forth by Kant to that of Empedocles. If one associates Kant's "order" and "chaos" with Empedocles's "Love" and "Strife" (respectively), a very striking likeness emerges. In fact, the perspective indexed to the observer within Kant's structure (as described in the preceding paragraph) might be summarized precisely as in the passage by Empedocles in his corresponding section from Chapter 2. Cases like this provide the driving force behind the present investigation, for one can see clearly here that the multiverse concept repeatedly materializes in familiar ways, yet historically it fails to cohere into a proper tradition.

3.13 Friedrich Nietzsche (1844-1900)

Nietzsche's doctrine of eternal recurrence is the means by which he enters the multiverse tradition. Perhaps the most famous description offered by Nietzsche is passage 341 from *The Gay Science*:

> What, if some day or night a demon were to steal after you into your loneliest loneliness and say to you: "This life as you now live it and have lived it, you will

[66] Kant (1981), p. 154. A typographical error in the original has the first word of the passage as "It," but that has been corrected here.

[67] Kant discusses galaxies and astronomers' observation of them, for example, on p. 200 in Kant (1981).

> have to live once more and innumerable times more; and there will be nothing new in it, but every pain and every joy and every thought and sigh and everything unutterably small or great in your life will have to return to you, all in the same succession and sequence—even this spider and this moonlight between the trees, and even this moment and I myself. The eternal hourglass of existence is turned upside down again and again, and you with it, speck of dust!"[68]

Posited as such, one may question both whether Nietzsche intends to postulate the concept as reality, and also whether the doctrine is meant ethically or scientifically. Without confirmation that Nietzsche intended the doctrine to be both actual and scientific, Nietzsche's postulation would rightfully lie outside the multiverse tradition.

There is strong evidence, though, that Nietzsche did propose the model both as reality and with scientific intent. He claimed that the doctrine was "the most *scientific* of all hypotheses," and Nietzsche searched for a means by which to prove that the theory obtained.[69] The details involved will not be pursued here.[70]

The model thus presented is one akin to the models proposed by some of the ancients (Anaximander, Heraclitus, and Empedocles), by Hume, and by Kant.[71] The miniverses are separated from each other temporally. There is one exceptional difference that separates Nietzsche's multiverse from the other temporal models proposed before his time: for Nietzsche, the universe and each of the other miniverses are *identical* to each other. This makes Nietzsche's multiverse a rare breed: one that espouses the most extreme form possible of the Typicality assumption.

3.15 Segue

Though the turn of the 20th century may seem an arbitrary point to draw the divide between the modern and contemporary eras, a divide nonetheless needs to be made. Thus, with Nietzsche, we

[68] Nietzsche (1974), p. 273.
[69] Kaufmann, in the introduction to Nietzsche (1974), attributes the quote to note 55 of *The Will to Power*, and Danto (1980) references p. 856 of Nietzsche's *Unpublished Notes*.
[70] For details concerning Nietzsche's claim that eternal recurrence was both actual and scientific, and for a reconstruction of Nietzsche's attempted proof at demonstrating it, see section 5 (pp. 15-21) of Kaufmann's introduction to Nietzsche (1974) and chapter 7 (especially pp. 203-209) of Danto (1980).
[71] The similarity to Kant obtains when describing Kant's multiverse "from within," as previously discussed in the section dedicated to Kant.

will deem the modern era closed and the contemporary era begun. With the main characters from two eras of the multiverse tradition now collected and their multiverse models catalogued, the time has come to begin the task of imparting order to the tradition.

4
Classification of Multiverse Structures

There are a multitude of contemporary multiverse models, and more are being generated continually. The historical exposition of multiverses from the ancient and modern eras is sufficient for generating a classification scheme for multiverse models. This classification scheme will then form the grid into which contemporary examples can be slotted.[1]

The historical episodes of multiverse thought are in need of classification. The task will be undertaken in two phases: first, with respect to classifying the multiverse constructs themselves, and second, with respect to classifying the arguments provided in support of such multiverse constructs.[2] The process, upon completion, will admit a cleanly organized storage unit where currently there resides only a single historical "dustbin" cluttered with models and arguments of all sorts.

Nicole Oresme has remained absent from mention thus far for two reasons. First, he does not fit into the set of ancient multiverse thinkers presented in Chapter 2 because he did not subscribe to multiverse cosmology. This much he makes clear in his closing lines on the subject in Book I of *Le Livre du ciel et du monde*:

> Therefore, I conclude that God can and could in His omnipotence make another world besides this one or several like or unlike it. Nor will Aristotle or anyone else be able to prove completely the contrary. But, of course, there has never been nor will there be more than one corporeal world, as was stated above.[3]

However, this sentiment does not straightforwardly exclude him from the multiverse tradition. In fact, Oresme holds a noteworthy position in the tradition. Despite his personal non-multiverse

[1] This strategy avoids the inevitable shortcoming that would be inherent in attempting to list the contemporary multiverse theorists individually, as was done in the ancient and modern cases. With new variants constantly emerging, no compendium could remain up-to-date. For this project, the classification scheme presented in this chapter circumvents the need for a complete compendium of the contemporary theorists, because the emphasis in the ensuing chapters is placed upon the philosophical and conceptual details, rather than on the formal details, of the multiverse hypothesis. The classification scheme will capture the relevant information (with particular models given as examples) while leaving out the non-crucial facets.
[2] The first task will be carried out in this chapter; the second will be carried out in Chapter 6.
[3] Oresme (1968), pp. 177-179.

stance, he is the earliest to create a meaningful classification system for multiverse thought.[4] This is the second, and more important, reason for omitting mention of him until this point in the historical display.

In his attempt to establish that the multiverse is not an actuality, Oresme describes and then attacks each of three different multiverse "types," examples of which are readily recognizable from the set of historical models presented in the preceding chapters. He writes:

> I say that, for the present, it seems to me that one can imagine the existence of several worlds in three ways. One way is that one world would follow another in succession of time, as certain ancient thinkers held that this world had a beginning because previous to this all was a confused mass without order, form, or shape…Another speculation can be offered which I should like to toy with as a mental exercise. This is the assumption that at one and the same time one world is inside another so that inside and beneath the circumference of this world there was another world similar but smaller…The third manner of speculating about the possibility of several worlds is that one world should be [conceived] entirely outside the other in space imagined to exist…[5]

As the ellipses indicate, this is an extended passage in which Oresme gives further thought to each of the types of models. By classifying the multiverse according to how the miniverses are related to each other, Oresme is able to generate argumentation against multiverse *types* rather than merely against the specific *models* proposed. This is a noteworthy approach to developing the tools necessary for grappling with multiverse argumentation. Also noteworthy is Oresme's opening qualification: he says that *for the present,* the existence of several miniverses can be imagined in three ways. This hints at the possibility of imagining multiverse models in ways different from the three he suggests. A classification scheme that is flexible enough to accommodate the emergence of novel models is therefore desired.

Oresme, in fact, was not the first to classify multiverse models, but he was the first to do so systematically. Others in the ancient era mention multiverse theorists, but only in contrasting them with cosmologists who postulate a single universe. Simplicius, for example, classified cosmologists in his commentary on Aristotle's *Physics*, but he did so only to the extent that they were broken into those who maintained "innumerable worlds" and those who maintained "a single

---

[4] I qualify Oresme as the first with a *meaningful* classification system for multiverse models because, as will be explained in short order, there have in fact been others who created classification schemes and dealt with multiverse thought. Oresme, however, is the first to give thorough, systematic thought to the matter.

[5] Oresme (1968), pp. 167-171.

world."[6] Aristotle considers the multiverse hypothesis in his *Physics* (as can be surmised from the fact that Simplicius comments upon this very passage of Aristotle's) in even less detail than Simplicius, writing that

> Some, however, claim that change is eternal; this is the view of those who say that there are infinitely many worlds and that some of these worlds are coming into existence, while others are being destroyed (for change must be involved in the process of coming into existence and being destroyed which the worlds undergo). On the other hand, those who claim that there is only one world make it either eternal or not eternal, and then they make corresponding assumptions about change as well.[7]

As is clear, Aristotle's focus here is the concept of change, and his brush with classification involving the multiverse is merely coincidental to that purpose. Examples of this sort do not have the depth of analysis supplied by Oresme, and for that reason Oresme's contributions simply are more substantial.

After Oresme, much time passes before meaningful classificatory multiverse work resumes. In fact, it is not until the contemporary era that additional contributions surface. Gale, Tegmark, and Trimble are the chief contributors, each classifying the multiverse by splitting it into categories.[8] Gale's scheme splits the possibilities into categories that he names "Spatially Multiple Universes," "Temporally Multiple Universes," and "Other-Dimensional Multiple Universes."[9] The titles of those categories carry apt descriptors of their contents. Tegmark's scheme includes four cryptic "levels" that he simply denotes I, II, III, and IV.[10] Level I includes an infinite expanse of space with miniverses located within, but separated to causally disconnected distances. Into Level II, Tegmark lumps two types of multiverse. The first includes miniverses that are separated into inflationary bubbles, and the second includes temporally cyclic miniverses. Level III is the name Tegmark attributes to Everett's branching interpretation of quantum mechanics, with each branch representing a miniverse. Finally, Level IV includes miniverses that collectively exhibit

---

[6] For more details on the account of Simplicius, see Burnet (1920) and Cornford (1934). Interestingly, within the "single world" category, Simplicius placed a model very similar to what will be labeled the temporally extended multiverse below.
[7] Aristotle (1996), p. 185.
[8] Davies (2004) provides another recent account, particularly in his section 2, which is entitled "Varieties of Multiverse." However, Davies is dedicated to listing and describing the various multiverse models that have been proposed, rather than *classifying* them, as is the goal for Gale, Trimble, Tegmark, and the present chapter. Additionally, see pages 5-6 of Rubenstein (2014) for a light classification scheme imbued with the qualities implemented by Tegmark.
[9] These are the subheadings for Gale's historical descriptions found in Gale (1998), pp. 196-200.
[10] See Tegmark (2004).

all possible mathematical structures, which involves letting the laws of physics vary from miniverse to miniverse. Trimble breaks multiverses into four categories that she labels "Hierarchical or Fractal," "Oscillating or in Temporal Succession," "Acausal Separation," and "General Relativistic and Beyond."[11] The first three categories offer suitable descriptions of their corresponding multiverses.[12] However, the fourth category amounts to a catch-all that includes branching quantum mechanics, inflationary models, and miniverses that collectively exhibit the possible relativistic cosmological models.

This is a mess that needs to be eliminated if a proper elucidation of the multiverse tradition is to be had. Of the foregoing, only Gale includes the rationale for the adoption of his partitions. On this front Gale succeeds where the others fail: he straightforwardly attempts to carve up the possibility space. This much is evident when he claims that "Multiple-universe models may be classified according to the means by which each model's universes are separated from one another: space, time, or some other dimension."[13] This clean method of reasoning will be employed in what follows, though we will see that Gale's classification admits of further subdivision, the inclusion of which is necessary for a complete description of the possibility space for multiverse models.

4.1 Division of Miniverses in Space

The most prevalent proposed means of separating miniverses, and the simplest to envision, is spatially. Imagine, as so many of the preceding authors have, a single expanse of space within which miniverses—causally disconnected from each other, yet still topologically connected to each other—exist within the same three-dimensional space.[14] This type of multiverse will henceforth be referred to as a *spatially extended* multiverse. Pictorially, one might envision the spatially extended multiverse in the following way (in two dimensions):

[11] These are the subheadings afforded by Trimble (2009), pp. 763-767.
[12] By "hierarchical or fractal," Trimble refers to multiverses whose miniverses are nested within each other.
[13] Gale (1998), p. 196.
[14] There is no necessity to restrict the number of dimensions to exactly three. The crucial facet of this type of model is that the miniverses are separated in the spatial dimension(s).

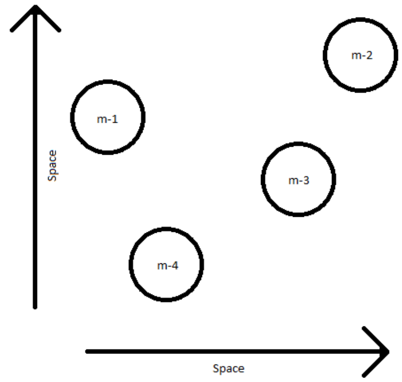

Figure 1: The spatially extended multiverse.

Remember, this general category is not intended to be tailored to any specific multiverse model, so it is important to refrain from applying specific questions to the category as a whole. (These questions might include, for example, the natural inclination upon looking at Figure 1 to inquire "How far apart are m-1 and m-2?")

As physical theories of nature have progressed, so, too, have conceptions concerning "causal disconnection." Gilbert's passages referenced in Chapter 3 provide a nice example. Gilbert maintains that each globe (which plays the role of the miniverse in his multiverse) exudes its own sphere of influence, attracting matter of its kind and repelling matter of other globes. Likewise, we witnessed in the writing of Huygens the explicit claim that the vortices (which are the miniverses for Huygens) "do not at all intermix or communicate with one another." Both examples convey the intent to keep miniverses causally separated from each other, though they nevertheless exist within the same connected space. Today, in a field dominated by the General Theory of Relativity, one immediately relates the concept of causal connectedness with the concept of space-like separation of events. But it is crucial to recognize that stripping away presently adopted *definitions* of causal connection—in favor of the basic *concept* of causal disconnection—unlocks arguments and philosophical insight from past ages. Even though the *definition* of causal disconnection has changed from theorist to theorist, authors from the past collectively envisioned the same *concept*, namely the inability of two objects or places to have any causal effect on each other. By recognizing that each writer works with the same concept, one suddenly grasps a likeness that bonds the writers together within the category. The likeness stretches from the ancient era to the contemporary era, and the multiverse tradition coheres.

There is a second means by which two miniverses could be separated within the spatial dimension. As was suggested by Cavendish, Pascal, and Boscovich, miniverses could be “nested” within each other. This corresponds to the spatial dimension(s) of one miniverse wholly enclosing the spatial dimension(s) of another miniverse. The miniverses are separated not by extension within the spatial dimension(s), but rather by scale. The scaled miniverse is, properly speaking, spatially located within the “parent” miniverse, yet it is causally disconnected from the parent miniverse. Henceforth this multiverse will be referred to as a *spatially scaled* multiverse. In pictorial fashion, very roughly:

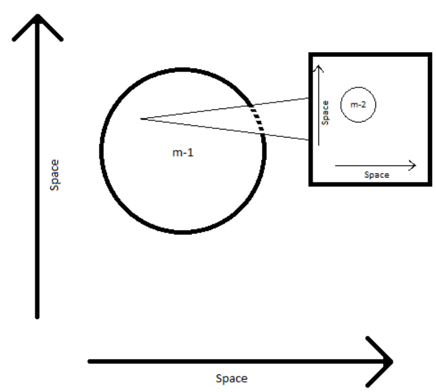

Figure 2: The spatially scaled multiverse.

Note that the spatial dimensions within m-2 are scaled versions of those governing m-1; the authors proposing this type of multiverse typically maintain that the scaled miniverse (m-2 in this case) is, subjectively from within it, very much like the parent miniverse (m-1) within which it is embedded.

Though the spatially scaled multiverse might at first glance appear to be nothing more than an historical artifact to be recognized but not taken seriously due to rigorous experimental progress, this is not the case. In Chapter 5, we will see a contemporary multiverse construct that fits the spatially scaled classification.

4.2 Division of Miniverses in Time

The separation of miniverses via the dimension of time is, according to what is known of the multiverse tradition, the earliest type of multiverse to be postulated. Anaximander, Heraclitus, and

Empedocles all advocated miniverses that were separated from each other temporally. Models of this type propose miniverses strung out linearly in the temporal dimension as depicted below:

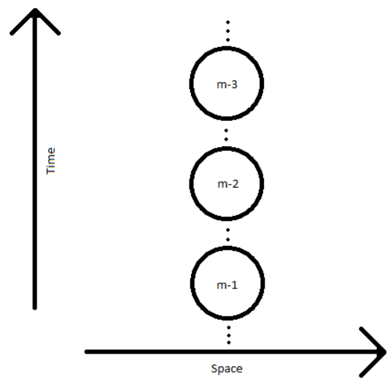

Figure 3: The temporally extended multiverse.

One interesting feature of the temporally extended multiverse involves its relationship to the spatially extended variety. Note that if the axes were switched, we would be left with a depiction of many contemporaneously existent miniverses within the same space. This, essentially, captures the parameters of the spatially extended multiverse, which highlights the symmetry of the classification scheme under construction. To be sure, there exists an experiential difference between the dimensions of time and space, but conceptually, separation in one type of dimension and separation in the other type should be treated uniformly, particularly at the abstract level (that is, independently of any particular multiverse proposal). Essentially, separation is separation, and the classification scheme under creation here recognizes separation in space and separation in time in a uniform way.

As with the multiverses classified according to spatial separation, temporally separated multiverses can arise in a second way. Of this, Boscovich provides an example. He postulated that within a spatially scaled multiverse, time proceeds correspondingly faster for the entities there. Boscovich's conception includes the temporal dimension of one miniverse wholly encapsulating the temporal dimension of another miniverse. In keeping with symmetry, this type of multiverse will be called a *temporally scaled* multiverse. Because our experience shows us only a single dimension of time, it is exceedingly difficult to envision a temporally scaled miniverse in relation to a "normally scaled" miniverse. Perhaps one way to do so might be this: just as we used abstraction to remove one spatial dimension in the depiction of the spatially scaled multiverse, we might likewise use "reverse" abstraction to include an extra temporal dimension as follows:

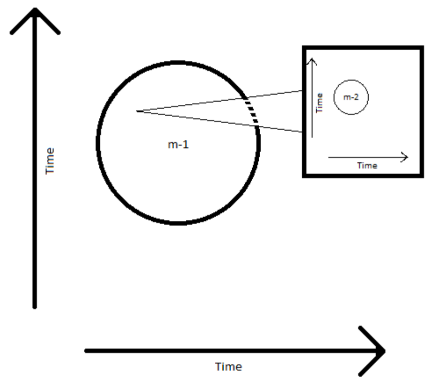

Figure 4: The temporally scaled multiverse.

This type of "reverse" abstraction, though difficult to comprehend, is nevertheless necessary in this case. It is important to disentangle our inherent association between the temporal dimension and the spatial dimensions in this case, and that requires that none of the depicted dimensions be of the spatial type. An example nicely illustrates why it is important to keep the temporal and spatial dimensions separate. Recall Boscovich's original postulation concerning the scaling of the temporal dimension: he proposed that the beings for whom the spatial dimension are scaled would likewise experience a scaling in the temporal dimension. But that need not be the case; one can consistently envision a spatially scaled miniverse that does not include temporal scaling. (Cavendish, presumably, envisioned exactly such miniverses with her earring example, since she made no mention of temporal scaling within those miniverses.) Thus, the concepts of spatial scaling and temporal scaling need to be dissociated from one another, leaving a separate, non-spatial form of scaling. A proper appraisal of Boscovich's proposal involves recognizing that it is scaled in *two* ways: spatially and temporally.[15]

4.3 Division of Miniverses in Other Dimensions

We have but a single example from the modern era that introduces the final type of multiverse. Boscovich, recall, described a miniverse located "elsewhere in such a way that it has no communication with this space of ours; & thus will induce no relation of distance."[16] The same,

[15] Further analysis of Boscovich's proposal appears in Section 4.5.
[16] Boscovich (1966), p. 199.

he continued, could be true of a miniverse located outside of our familiar temporal dimension. Miniverses that are not related to one another via spatial or temporal distances thereby cannot be described in terms of any of the partitions previously described; no relationship exists with which to orient the miniverses with respect to each other along those familiar dimensions. A multiverse comprised of such miniverses will be labeled a *dimensional* multiverse. Whereas the ancient and modern eras generated multiverse models dominated by the spatial and temporal varieties, we will see that the contemporary era of multiverse theorizing is heavily populated with dimensional models.

Dimensional multiverses exhibit some similarity to the other multiverse types in that there are two distinct ways of envisioning their construction. The first of these is closest to what Boscovich portrays. The miniverses, simply put, have absolutely no relationship to one another. Thus, there is no way pictorially to orient two such miniverses with respect to each other beyond simply placing them on separate, disconnected diagrams:

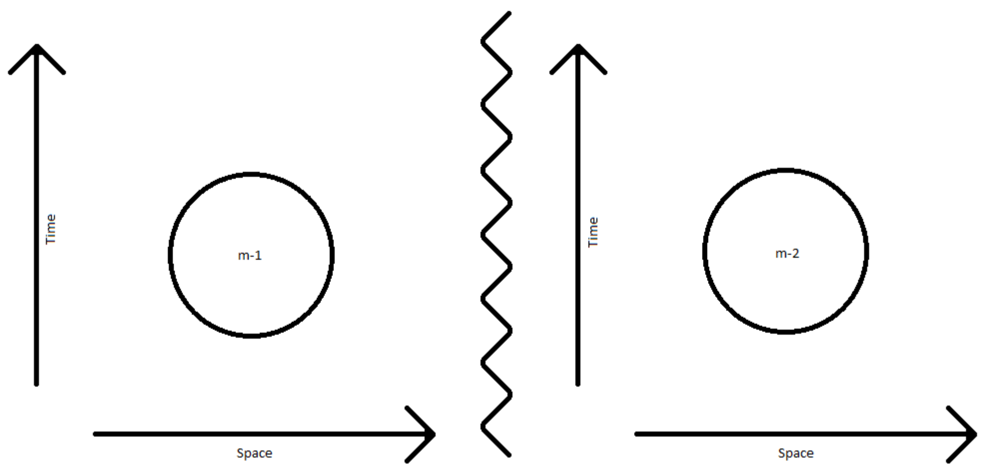

Figure 5: The dimensionally separated multiverse.

Such multiverses will be labeled *dimensionally separated* multiverses. The jagged line in Figure 5 indicates the complete separation of the two miniverses with respect to the spatial and temporal dimensions. Importantly, note that this type of multiverse fails to satisfy the requirement that the miniverses be topologically connected; as such, this variant is included largely to accommodate Boscovich's modern-era model.[17] However, recognizing the dimensionally separated multiverse

[17] Further foundational reasons for including the dimensionally separated multiverse within the classification scheme is presented in Chapter 5.

also leaves a marker within the classification scheme for the inclusion of such constructs, should the "topological connection" requirement be relaxed.

The second type of dimensional multiverse is far more prevalent in the tradition, particularly within the contemporary era. Miniverses in the second type of dimensional multiverse exhibit no measurable relationship to each other with respect to the spatial or temporal dimensions, but they are presumed to be locatable with respect to each other via some other dimension. By way of example, recall that the miniverses in a temporally extended multiverse exhibit no measurable relationship to each other in the spatial dimension; their location with respect to each other lies in the temporal dimension. Likewise, two miniverses could exhibit no measurable relationship to each other in either the spatial or temporal dimensions, but nevertheless the miniverses could be topologically linked via some *other* dimension. A multiverse of this sort will henceforth be called a *dimensionally connected* multiverse, and might be depicted as follows:

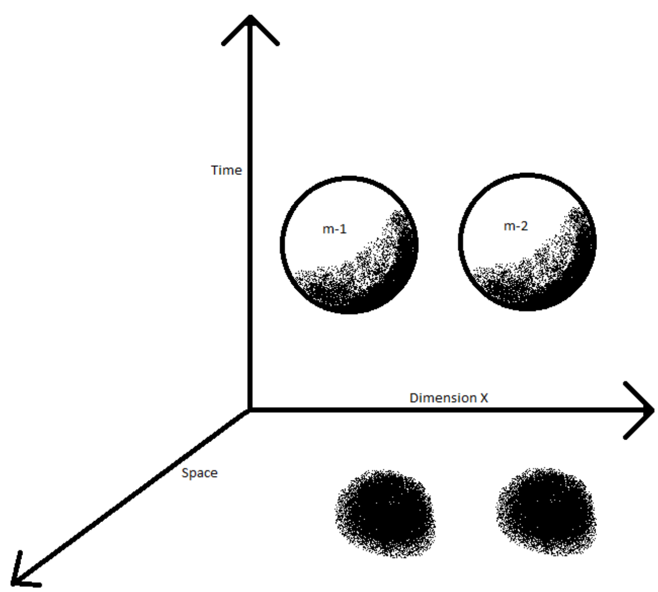

Figure 6: The dimensionally connected multiverse.

The depiction in Figure 6 involves three dimensions—though that need not be the case for all dimensionally connected multiverses—because this depiction emphasizes the lack of relationship (with respect to distance) between m-1 and m-2 in both the spatial and temporal dimensions. There is no difference between the two miniverses with respect to space and time. Only the third dimension (here labeled "Dimension X") exhibits a difference: m-1 and m-2 are locatable with respect to each other in dimension X. There is distance between them in the X-dimension. We will see several examples of the dimensionally connected multiverse in Chapter 5, but a brief example here will be useful. In what are commonly referred to as “brane” multiverses, the miniverses take the form of multi-dimensional “branes” that are embedded in higher-dimensional spaces. The extra dimensions are neither temporal nor spatial (in the typically understood sense of our familiar three spatial dimensions), yet nevertheless they provide a means of topologically locating the miniverses with respect to each other.[18] Details of this multiverse model, as well as examples of others from the contemporary era, occupy Chapter 5.

4.4 Interlude

A strong case can be made for the adoption of the classificatory scheme presented here. Its pragmatic uses—especially for referential purposes—are evident, and its usefulness as a tool for sparking constructive analysis of multiverse theory will be made apparent in the coming chapters.

The opportunity should be taken, however, to present solid foundational reasons for adopting this classification. Specifically, we can see that the scheme straightforwardly accounts for each possible multiverse model, and in that sense, it is a complete classificatory system. Thus, Gale’s blueprint for a structured approach has been successfully implemented. The transition to this scheme is eased by the fact that there is a principled, logical means by which the possibilities have been partitioned. This eradicates the feeling of disorganization imparted by the classification structures proposed by Tegmark and Trimble. In place of that confusion, we have clean categories: the spatially extended and spatially scaled categories account for miniverses that are separated from each other spatially, the temporally extended and temporally scaled categories account for miniverses that are separated from each other temporally, and the dimensionally separated and dimensionally connected categories account for miniverses that are separated from each other in a non-temporal and non-spatial way. Since any two miniverses that are separated from each other must be so with respect to an expanse of space, a duration of time, or by some extra-dimensional

[18] One such example is provided in Randall & Sundrum (1999). There, it is argued that 3-branes can exist within a non-compactified 5-dimensional space in consistent harmony with our gravitational observations, thereby making the dimensionally connected multiverse a possibility via a model of that sort.

measure, we see that any multiverse must properly be described as falling into one of the six categories.[19]

Success has been found through capturing the lessons learned from the previous approaches of Oresme and Gale. Gale's broad strategic outline was obeyed with respect to breaking the multiverse proposals into classes according to miniverse separation via space, time, or some other dimension. The further partition of each of these classes into two types provides comprehensive specificity without sacrificing the simplicity of his classification. For example, where Gale broadly admits "Spatially Multiple Universes," which would include both Bruno and Pascal as category-mates, the present proposal separates them into their respective "extended" (Bruno) and "scaled" (Pascal) categories while maintaining their relationship to each other in the "spatial" class.

Additionally, Oresme's hearkening to a classification structure that is capable of adaptation to unforeseen theoretical constructs has been successfully realized. The presented scheme encourages deeper objective analysis within the tradition by recognizing that the temporal and spatial dimensions—with which we are inherently shackled, owing to our universe and our perceptive faculties—need not exhaust the possibilities for multiverse models. Though we are currently incapable of resolving possibilities beyond the spatial and temporal dimensions, we need not exclude the notion altogether. Rather, for the sake of exhaustiveness, we capture those possibilities within the dimensional class, which could be further subdivided should the need ever arise. Additionally, the current subdivision of each type into two subcategories could be expanded, should a multiverse model surface in which (for example) a novel form of spatial separation is posited. (This would be a form of spatial separation that is neither extended nor scaled.)

[19] There may be dispute about how to classify a "tiered" multiverse that possesses miniverses that are separated from each other in one sense while simultaneously exhibiting separation in another sense. For example, Cavendish's complete multiverse conception consists of an extended-spatial multiverse whose miniverses themselves each exhibit scaled-spatial qualities. It is not evident which category "takes precedence" in this example, so it is not immediately evident which category Cavendish's multiverse falls into. Note, however, that the description in this instance would be either "spatially scaled" or "spatially extended." In that sense, the classificatory scheme is complete because it harbors all of the possible models, even if it is not readily apparent which of the six descriptors applies in certain cases.

4.5 Tiers

With the possibility space for miniverse separation exhausted, attention may be given to a further necessity for a complete classification of multiverses. Recall once more this description from Boscovich:

> Is it not possible that there be a long series of such worlds, which, with respect to one another have the same relation as our single grain of sand has to the whole world?
>
> …
>
> Whatever the truth of the matter, it really seems beyond doubt that what is for us a vanishing instant seems to be a very long time to those very tiny living beings. In this respect it occurs in those little animals something similar to what we observe in the pendulums of a shorter length whose number of oscillations is in a given time so much larger, the shorter is their length. So these very tiny living beings,…, if they pass through three or four generations in a day, regard this day as a century.[20]

This is a proposal for a multiverse that is scaled both spatially and temporally. The miniverses, strictly speaking, are separated from each other in *two* ways: the spatial dimensions are scaled and the temporal dimension is also scaled. Or, likewise, consider Cavendish's complete theoretical construct. It is a spatially extended multiverse, but it also contains spatially scaled miniverses (as exemplified by her earring example). For these models proposed by Boscovich and Cavendish, one cannot unequivocally decide which description is the proper description for the multiverse. It is not clear whether the proper description of Boscovich's multiverse is spatially scaled rather than temporally scaled, and it is not clear whether the proper description of Cavendish's multiverse is spatially extended rather than spatially scaled.

The problem is solved by recognizing that the multiverses proposed by theorists may admit of *tiers*. Simply put, an *n*-tiered multiverse consists of miniverses separated in *n* ways according to the classification scheme presented in this chapter. Thus, Cavendish and Boscovich each propose a 2-tiered multiverse in their respective passages.

The versatility—and, correspondingly, the utility—of implementing tiers comes to fruition upon noting that they serve two distinct functions. First, tiers aid in classifying multiverses objectively. Noting, for instance, that Cavendish's multiverse is 2-tiered eliminates the pressing need to wedge her model into only one of the multiverse types. Thus, while foundationally only

[20] Boscovich (1976), p. 225.

six distinct types of multiverse have been identified, the implementation of tiers expands the classification scheme in an objective way that accounts for the nuances and idiosyncrasies of the myriad models proposed in the multiverse tradition.

But there is a deeper utility afforded by recognizing tiers. Because typicality is an inherently indexed relationship (that is, something can only be typical according to its relationship to other things), one needs to specify the population under consideration in order to determine whether a sample is typical or atypical. Tiers permit one to perform exactly this specification with respect to miniverses within a multiverse. For example, a miniverse that is typical (in some way) within a single tier of a multiverse may be atypical when compared to the set of all miniverses in all tiers of that multiverse. For the purpose of philosophical argumentation, this is an extremely powerful tool that can elucidate the basis for, and implications of, typicality assumptions. In particular, tiers can provide the foundation for defining typicality assumptions: the typicality (or atypicality) ascribed to a miniverse can be indexed and measured according to the tier(s) in question.

4.6 Segue

With the inclusion of tiers, we are poised to put the classification scheme to use. We may situate each of the historical thinkers in his or her proper place in the following way:

Separation Type					
Temporally		**Spatially**		**Other (Dimensionally)**	
Extended	*Scaled*	*Extended*	*Scaled*	*Separated*	*Connected*
Anaximander Heraclitus Empedocles Hume Kant[1] Nietzsche	Boscovich[1,2]	Leucippus Democritus Diogenes Epicurus Lucretius Cusanus Palingenius Gilbert Bruno More Cavendish[1] Huygens Wright Kant[1]	Cavendish[1] Pascal Boscovich[1,2]	Boscovich[2]	None[3]
Notes: 1—Tiered multiverse 2—Multiple models proposed 3—There are no models from the ancient or modern eras of this type					

Figure 7: The classification of ancient-era and modern-era thinkers in the multiverse tradition

Analysis of the final era in the multiverse tradition, to which we now turn, will put the multiverse classification scheme to use by organizing the most widely regarded multiverse models proposed in the contemporary era.

5
Contemporary Multiverse Models

With the general classification scheme for multiverse models in place, some of the more prominent contemporary multiverse models can be classified. It is important to emphasize once more that unlike the ancient and modern classes of multiverse models, the contemporary class continues to grow, so an exhaustive index cannot be had. Instead, the contemporary models are introduced via examples within each class of multiverse structure. The most prominent models in each class will be detailed, with mention and references to other noteworthy category-mates closing out each section. This will afford the interested reader the ability to further pursue some of the lesser-developed (or under-publicized) models without causing this section to sprawl uncontrollably as it would be wont to do if every contemporary model (and corresponding author) were given the space allocated to the historical models (and authors) in Chapters 2 and 3.

The overall goal is a demonstration of continuity between the historical models and the contemporary ones with respect to the classification system generated in Chapter 4. Such continuity, once achieved, will result in the coherence of the corpus of multiverse literature into a veritable tradition wherein legitimate lessons from early in the tradition can be brought to bear on contemporary thought. The inclusion of tiers in the classification system will prove indispensable throughout the discussion of contemporary models, as explicit analysis of most contemporary models will reveal tiered systems.

5.1 Spatially Extended Multiverses

The versatility of the concept of tiers can be put to use immediately when sampling the contemporary literature for spatially extended models. Vilenkin, who proposed as early as 1982 that quantum cosmology and eternal inflation imply the existence of spatially extended miniverses, champions one of the most prominent models.[1] Vilenkin's model is instructive with respect to demonstrating the necessity of tiers for imparting clarity to the multiverse tradition. He theorizes, in his earlier publications on the subject, about the means by which a universe could arise from nothing.[2] This thought expands into a multiverse scenario:

> My approach is based on the picture of the universe suggested by quantum cosmology and by the inflationary scenario. In this picture, small closed universes spontaneously nucleate out of nothing, where "nothing" refers to the absence of not only matter, but also of space and time. All universes in this metauniverse are disconnected from one another and generally have different values for some of the constants. This variation may be due to different compactification schemes, wormhole effects, etc.[3]

On the surface, this passage unmistakably portrays a dimensionally separated multiverse: the miniverses share neither space nor time dimensions with each other. However, it becomes evident that this initial summary only depicts one set of the miniverses contained within Vilenkin's multiverse. The other set—and the set to which Vilenkin has since devoted the most attention—forms a spatially extended multiverse *within* each of the miniverses in the dimensionally separated multiverse.

Vilenkin's focus narrows to the contents of a single miniverse, namely our universe. He writes, for example, that

> The eternally inflating spacetime [one of the dimensionally separated miniverses] contains an infinite number of island universes [the spatially separated miniverses]. However, since each island universe is itself spatially infinite, it is sufficient for our purposes to consider a single island universe.[4]

The tiered structure of Vilenkin's multiverse model is clearly evident. The important ramification of recognizing that Vilenkin's model is tiered is this: Vilenkin makes many claims throughout his works that involve the probability distributions of miniverses and their contents, but often he fails to index such distributions to the tier of miniverses involved in his calculations. For example, consider Vilenkin's assertion that "We can calculate the probability distribution for an observer

---

[1] For Vilenkin's full account, see his various publications on the issue, including Vilenkin (1982); Vilenkin (1984); Vilenkin (1995); Garriga & Vilenkin (2001); Knobe, Olum, & Vilenkin (2006); and Vilenkin (2010). Though Vilenkin works with collaborators in several of his multiverse writings, I will here present the model as Vilenkin's body of thought, since his presence is the constant thread through all of the considered works.
[2] See Vilenkin (1982) and Vilenkin (1984).
[3] Vilenkin (1995), p. 846.
[4] Knobe, Olum, & Vilenkin (2006), p. 50. I have inserted the bracketed additions for clarity with respect to this project's terminology.

randomly picked in the universe to measure a given value of ρ_v [the cosmological constant]."[5] Such claims have argumentative import, but the content of that import is tethered to an underlying assumption (the typicality assumption) that defines the set of miniverses involved in the claim. The matter is further complicated by the fact that there is evidence—though it could be considered "trace" evidence—that Vilenkin's model is actually 3-tiered, with the third tier being a temporally scaled tier. We will set aside that complication for the moment.[6] Here, Vilenkin does not specify which set of miniverses is involved in the calculation he proposes, though it is fairly evident from context that he refers to the spatially extended tier of miniverses. Elsewhere, and with other theorists and their models, the context is not so evident, nor do the claims made (by Vilenkin or other theorists) necessarily hold true across different tiers of the multiverse. (For example, note the difference involved if Vilenkin were referencing the dimensionally separated tier of miniverses rather than the spatially extended tier: many more assumptions would be required simply to establish the claim that *there exists* a probability distribution for the value of ρ_v over the miniverses, let alone to establish the claim that we could ascertain such a value for a particular miniverse.)

For now, we will postpone further analysis of the interplay between tiers and typicality assumptions, except to note one further consequence. A typicality assumption is coherent only insofar as it governs an explicit set of miniverses. Defining explicit sets of miniverses is precisely what tiers accomplish. Thus, in a tiered model, typicality assumptions are directly linked to the tiers of the multiverse in question. Since important argumentative ramifications are linked to the underlying typicality assumptions, it follows that the deployment of tiers is absolutely essential to a proper philosophical analysis of the multiverse concept.

Aside from an exemplary model for displaying the importance of tiers to the analysis of multiverses, Vilenkin's work also provides a glimpse at the links between earlier episodes of multiverse thought and contemporary ones. For example, when Vilenkin writes that

> the number of different ϑ regions [the interiors of past light cones from the time of recombination up to the present] in the universe is infinite, and thus there should be an infinite number of other regions with histories identical to ours. Moreover, all histories which are not strictly forbidden by conservation laws occur in a finite fraction of the ϑ regions,[7]

[5] Vilenkin makes this particular claim in Vilenkin (2010), p. 2. Bracketed addition inserted for clarity.
[6] Vilenkin's temporally scaled tier will be the focus of Section 5.4.
[7] Garriga & Vilenkin (2001), p. 043511-1. Bracketed addition has been inserted for clarity.

one cannot help but be struck by the similarities to the passages cited earlier from Bruno and Hume. Upon recalling Hume's emphasis that

> every possible order or position must be tried an infinite number of times. This world, therefore, with all its events, even the most minute, has before been produced and destroyed, and will again be produced and destroyed, and without any bounds and limitations,[8]

there remains very little doubt that these writers from different eras grappled with the same collection of recurring concepts, themes, and difficulties.[9] Threads like this one are what tie multiverse thought into a tradition worthy of analysis. It should come as no surprise that several examples of this sort emerge from the full multiverse corpus.

We are to take two important notes from the preceding. First, Vilenkin's multiverse is two-tiered, with one tier involving miniverses being dimensionally separated and the other tier involving miniverses that are spatially extended. Owing to the fact that Vilenkin devotes the bulk of his attention to the tier of spatially extended miniverses in his multiverse, his model will be included among the contemporary spatially extended models. But, of course, it is evident that his model is two-tiered; each miniverse is dimensionally separated from one set of other miniverses and spatially extended from another set of miniverses. This means that we will see Vilenkin's model cross-listed with the contemporary dimensionally separated multiverse models.

Second, the spatially extended tier of Vilenkin's multiverse is similar in its parameters to the spatially extended model proposed by Bruno and others of the earlier eras. This leaves Vilenkin grouped with many others of the contemporary era who propose spatially extended models closely akin to the proposals from writers of eras past. Boltzmann's multiverse is composed of spatially extended miniverses that probabilistically thermalize in the vast expanse of the otherwise-thermally equilibrated multiverse.[10] Ellis and Brundrit present argumentation that closely matches the reasoning of Vilenkin (though they publish three years prior to Vilenkin's first work on the matter), concluding that spatially extended miniverses with "'duplicate' populations" are scattered about the multiverse.[11] By contrast with Vilenkin's position, and in conformity with Boltzmann,

---

[8] Hume (1947), p. 182.
[9] Some of the model-specific details, of course, separate the cases. Hume, for example, writes within the context of a temporally extended multiverse. Nonetheless, there is no question that the *concepts* described by both Vilenkin and Hume (concerning, for example, the repetition of miniverses, whether in the temporal or the spatial dimension) present an important likeness of thought.
[10] Boltzmann (1895), p. 415
[11] Ellis & Brundrit (1979), p. 37.

Ellis and Brundrit do not present a tiered multiverse. A general progression from non-tiered to tiered models in the contemporary class of spatially extended models emerges: Gott, writing just at the cusp of the influence brought about by Guth's introduction of inflation, likewise generates a non-tiered, spatially extended model that involves the formation of separated, spatially open miniverses within a shared space.[12] Sato, Kodama, Sasaki, and Maeda propose a non-tiered model in which very early during cosmic evolution, an initially shared portion of false vacuum is cut by true vacuum bubbles to form causally disconnected regions; these miniverses, thus separated, form a spatially extended multiverse.[13]

The later models tend to exhibit tiers. For example, the Baum-Frampton model exhibits a temporally extended tier in conjunction with its spatially extended tier.[14] Likewise, Linde postulates a tiered multiverse, one of which is spatially extended. The second tier in Linde's model invokes the string theory landscape to create a dimensionally connected tier of miniverses.[15] Susskind and Greene join Linde in describing two-tiered models, one of which is spatially extended. The dimensionally connected tier of the model espoused by Linde, Susskind, and Greene will be cross-listed and detailed in the section dedicated to dimensionally connected multiverses.

5.2 Spatially Scaled Multiverses

Finding spatially scaled multiverse models in the contemporary era initially may seem like a fruitless endeavor, since extensive probing into the subatomic realm has hinted at nothing of the sort. Thus, for example, Trimble claims that "quantum mechanical considerations exclude multiple worlds on scales smaller than our own."[16] Nevertheless, it seems that such models—of two general types—still are to be found. One type involves the possibility of miniverses existing

---

[12] Gott (1982).
[13] Sato et al. (1982).
[14] See Section 5.3 for more on the Baum-Frampton model.
[15] See Linde (2007a); Linde (2007b); Linde, Vanchurin, & Winitzki (2009); and Linde & Vanchurin (2010) for details. The intricacies of coupling the string theory landscape with inflationary cosmology will be addressed in Section 5.5.
[16] Trimble (2009), p. 764.

wholly within small regions of the universe, and the other type creatively places the universe as the "contained" miniverse, embedded within a larger-scale miniverse. Both types qualify as spatially scaled multiverses.

An example of the first type emerges in the cosmology proposed by Smolin. The first significant work he published on the matter appears in 1992, where Smolin describes the model as follows:

> Each final singularity is followed by an initial singularity, which evolves into a universe that is spatially closed. An alternative hypothesis, which is equivalent as far as its consequences for the subject of this paper, is that instead of an ending in a final singularity, the interior of a black hole tunnels into a new spatially compact universe.[17]

Smolin thus creates a scenario whereby the minute confines of a black hole's singularity wholly contain another miniverse.

The model has received extended treatment by Smolin. Having been dubbed Cosmological Natural Selection (CNS), it is constructed from three hypotheses:

> (a) A physical process produces a multiverse with long chains of descendants.
>
> (b) For the space $\mathcal{P}$ of dimensionless parameters of the standard model of physics, there is a fitness function $F(p)$ on $\mathcal{P}$ which is equal to the average number of descendants of a universe with parameters p.
>
> (c) The dimensionless parameters p_{new} of each universe differ, on average, by *small* random amounts from those of its immediate ancestor (i.e. small compared with the change that would be required to change $F(p)$ significantly).[18]

Thus, upon generation, a new miniverse born "on the other side" of its singularity exhibits values of the physical constants that are slightly changed from the values of the physical constants of the "parent" miniverse as described in CNS (c).[19] Additionally, "mature" miniverses can be assigned a "fitness" as described in CNS (b) according to the number of black holes present in that miniverse.

This leaves Smolin with a model in close association, for example, with that proposed by Cavendish; Smolin proposes a "world in a black hole" in place of her "world in an eare-ring." The

---

[17] Smolin (1992), p. 175.

[18] Smolin (2007), p. 351-352.

[19] Smolin's account requires that no singularity *actually* occurs at the core of the black hole; rather, "before the singularity is reached, densities and curvatures reach the Planck scale and quantum gravity dictates the dynamics…Time then does not end and there is a region of spacetime to the future of where the singularity would have been" (Smolin (2007), p. 335). In effect, this permits Smolin's account to satisfy *MULTIVERSE* (i) (see Chapter 1) by maintaining topological connectedness between the old and new miniverses.

miniverses, both for Smolin and for Cavendish, are separated not by extension or distance from each other, but rather by scale. Smolin even goes so far as to claim that the scaled miniverse is, subjectively from within it, very much similar to the "parent" miniverse; his CNS (c) effectively ensures the similarity. These two conditions—separation by scale rather than distance and similarity between the containing miniverse and the contained miniverse—were precisely the conditions outlined for the spatially scaled multiverse in Chapter 4. Other contemporary proponents of a scaled multiverse of this sort include Whitehead, who declares that

> We are too stuck up in our notions of size, measuring everything in proportion to our bodies. From what science has discovered about the infinitely small and the infinitely vast, the size of our bodies is almost totally irrelevant. In this little mahogany stand may be civilizations as complex and diversified in scale as our own; and up there, the heavens, with all their vastness, may be only a minute strand of tissue in the body of a being in the scale of which all our universes are as a trifle.[20]

Thus Smolin and Whitehead extend the reach of spatially scaled multiverse models from the modern era (examples from which included Boscovich, Cavendish, and Pascal) to the contemporary era.

We see the two conditions for spatially scaled multiverse models satisfied in a second way in the contemporary era. Typically referred to as "fractal" or "hierarchic" universes, multiverses of this sort are described by Norton as "matter grouped locally in clusters; then these clusters…in turn grouped into clusters; and the next level of clusters into a higher level of clusters; and so on indefinitely."[21] A structure of this sort fits the parameters of a spatially scaled multiverse, since as the base-level clusters combine to form the higher-level cluster, the physical constituents of the higher-level cluster resemble a larger manifestation of the base-level cluster. In this way, once again, the smaller-scale miniverse would very much resemble the larger-scale miniverse (but on a reduced scale), and the smaller scale miniverse would be wholly contained within the larger scale miniverse (the smaller being an actual copy—but nevertheless a part of—the larger). Thus, for example, the hierarchic models proposed by Fournier d'Albe, Charlier, and de Vaucouleurs slot into the contemporary spatially scaled multiverse category, joining Smolin and Whitehead.[22]

[20] Whitehead (1954), pp. 367-368.
[21] Norton (1999), p. 304.
[22] For the respective details of each of these accounts, see Fournier d'Albe (1907), Charlier (1922), and de Vaucouleurs (1970). Additionally, Norton (1999) contains an excellent summary of the historical context within which some of these hierarchic models were proposed.

5.3 Temporally Extended Multiverses

A contingent symmetry with the spatial class of contemporary multiverse models leaves the temporal class of contemporary models with most of its members residing in the temporally extended subdivision. We will see here a further likeness between the contemporary spatially extended and temporally extended classes: the earlier models are (predominantly) non-tiered, whereas the later models exhibit tiers.

Tolman, according to Gale's survey, was the first to produce some semblance of formalization of the temporally extended multiverse.[23] In 1934, Tolman described the model, familiar from historical eras past, in a fashion updated to incorporate the General Theory of Relativity. Though Tolman is careful to present the implications for each of the possible value-segments of the cosmological constant (Λ), he appears to favor argumentation for a temporally extended multiverse model wherein $0 < \Lambda < \Lambda_E$, with Λ_E representing the value for the cosmological constant that would produce a static Einstein universe:

> As the first type of behavior, we have those models which expand continuously into the future from some point on the critical curve…past the maximum, where a reversal in the direction of motion from a preceding contracting phase takes place. […] As a model of the actual universe, it again has the disadvantage of spending all but an infinitesimal fraction of its total existence in a condition unlike that which we observe. As a second type of behavior, we have models which expand from a singular state…to a maximum radius which lies on the critical curve where the direction of motion will reverse. The contraction thus initiated then continues, until expansion would again start at a singular state…As a model for the actual universe, it has the advantage of spending all its life in a condition where there is a finite density of matter, provided irreversible processes do not take place which alter the conditions for successive maxima. It has, of course, the disadvantages of a singular state at the lower limit of contraction, through which the mechanism of passage is not described by the present equations.[24]

The subtle argumentation that Tolman includes here for the temporally extended multiverse (due to its explanatory power) will receive attention in Chapter 6. For now, the importance resides in the update Tolman provides to a model that stretches from the ancient Greeks (Anaximander, Heraclitus, and Empedocles) through the modern period (Hume, Kant, and Nietzsche) to the contemporary era. Tolman's "mechanism of passage" through the singularity at the temporal end

[23] Gale (1998), p. 205.
[24] Tolman (1966), p. 401.

of a miniverse remains an unresolved issue. Wheeler revisits it in the creation of his model. Like Tolman, Wheeler does not permit the details regarding continuity from one side of a singularity to the other to diminish his support for a temporally extended multiverse. Instead, he simply labels the difficulty the "black box" and moves forward with the temporally extended model:

> Whether the whole universe is squeezed down to the Planck dimension, or more or less, before reexpansion can begin and dynamics can return to normal, may be irrelevant for some of the questions one wants to consider. Physics has long used the "black box" to symbolize situations where one wishes to concentrate on what goes in and what goes out, disregarding what takes place in between…Little as one knows the internal machinery of the black box, one sees no escape from this picture of what goes on: the universe transforms, or transmutes, or transits, or is *reprocessed* probabilistically from one cycle of history to another in the era of collapse.[25]

Wheeler's version of the temporally extended multiverse is perhaps the most well-known, at least in philosophical circles, though to be sure others propose similar models.[26] Landsberg and Park, for example, propose a very similar model.[27] Of note is that the models of Tolman, Wheeler, and Landsberg and Park are all non-tiered: these models, proposed during the early-to-middle portions of the contemporary era, each involve a single set of miniverses related to each other by distance in the temporal dimension.

Later models incorporate tiers. Kragh refers to these as "new cyclic models of the universe."[28] Authors such as Steinhardt and Turok propose sets of temporally extended miniverses separated from each other in a dimensionally connected way:

> Here, we present a cosmological model with an endless sequence of cycles of expansion and contraction…In our cyclic model, the universe is infinite and flat, rather than finite and closed as in the oscillatory models…[W]e find the connection [to string theory] useful because it provides a natural geometric interpretation for the scenario. Hence, we briefly describe the relation. According to *M*-theory, the universe consists of a 4D "bulk" space bounded by two 3D domain walls, known as "branes" (short for membranes), one with positive and the other negative tension. The branes are free to move along the extra spatial dimension, so that they may approach and collide.[29]

---

[25] Misner, Thorne, & Wheeler (1973), pp.1209-1214. Emphasis in original.
[26] See, for example, the exchange between Hacking (1987) and Leslie (1988), where this type of multiverse model is referred to as "Wheeler universes."
[27] See Landsberg & Park (1975).
[28] The title of chapter 8 in Kragh (2011) is "New Cyclic Models of the Universe," and though the focus there is placed on the new wave of tiered multiverse models involving a temporally extended tier, additional references to early-in-the-contemporary-era, non-tiered temporally extended multiverse models can be found on pp.194-202.
[29] Steinhardt & Turok (2002), pp. 1436-1437. The bracketed additions are included for clarity; the parenthetical phrase is included in the original text.

The reference to the "extra spatial dimension" and the additional fact that the branes collectively move along this dimension precisely fit the parameters of the dimensionally connected multiverse. The result, then, is a tiered multiverse model in need of cross-listing in the dimensionally connected category. Each individual brane represents a temporally extended tier of miniverses. The collection of branes constitutes a dimensionally connected tier of miniverses. Other late-contemporary-era, temporally extended models likewise exhibit tiers, which likens the contemporary class of temporally extended models to the contemporary class of spatially extended models in that respect.[30] For example, we see the Baum-Frampton model cross-listed with the spatially extended class.[31]

These contemporary authors join some of the most ancient thinkers in postulating miniverses separated from each other temporally. Anaximander, Heraclitus, and Empedocles of the ancient era, as well as Hume, Kant, and Nietzsche of the modern era, each proposed a temporally extended model very much in line with these contemporary authors.

5.4 Temporally Scaled Multiverses

From the historical set of models, we saw only one (issued from Boscovich) that occupied this class. Thus, given the relative similarities exhibited in the multiverse tradition between the historical and contemporary models, one might expect a likewise-diminished set of contemporary models in the temporally scaled class. This expectation is fulfilled.

Just a single model is on offer. In one iteration of Vilenkin's multi-tiered model, he provides rough details concerning the temporal relationship between miniverses. This brief account appears to conform to the requirements of a temporally scaled tier of miniverses:

> Remarkably, the entire universe, which contains all these infinite island universes, may be finite. The apparent contradiction is resolved due to the fact that the internal notion of time in island universes is different from the 'global' time that one has to

[30] See, for example, Kragh (2011), pp. 202-208, which provides deeper details of the Steinhardt-Turok model, and pp. 208-213, which provides further support for the claim that the earlier models of the contemporary era are non-tiered and the later models are tiered. The lone exception appears to be loop quantum gravitational models, which are late-contemporary-era models that nonetheless refrain from incorporating tiers beyond the temporally extended. Kragh likens the Baum-Frampton model to the Tolman model, but closer inspection reveals that the Baum-Frampton model exhibits a spatially extended tier in addition to the temporally extended tier, linking it more closely to the Steinhardt-Turok model than to the Tolman model. See Baum & Frampton (2007). See also Gale (1998) for further examples of contemporary temporally extended multiverse models, including that of Markov.

[31] See the previous footnote for details and references for the Baum-Frampton model.

> use to describe the entire spacetime. The volume of the universe at a particular global time may be finite, but the volume in an island universe at the time of the Big Bang in that universe (or any later time) is infinite.[32]

Though it may be the case that other models that implement eternal inflation likewise concur with the sentiment here expressed by Knobe, Olum, and Vilenkin, this passage sets the model apart in that there is direct, explicit mention of the differing scales of time exhibited within one tier of the multiverse.

The dearth of models in this class need not be discouraging. As described in Section 4.2, from a perspective of completeness, the inclusion of this class is desirable, since it is evident that it is one of the ways that theorists (even if very few) in the multiverse tradition have envisioned a separation between miniverses. The classification scheme is flexible in that it first sifts according to dimension *type* (i.e., space, time, or other), and then it sifts by *style* (i.e., extended, scaled, etc.). Additions to our collective knowledge of extant dimensions will result in additions to the *types* within the classificatory scheme, and additions to our collective knowledge about extant means of separation within known dimensions will result in additions to the *styles* of separation. The temporally scaled class is, simply put, a class which has received little attention within the tradition, though there should be no mistake that it is indeed a part of the tradition, owing to the fact that there are models which *do* employ it.

5.5 Dimensionally Connected Multiverses

Contemporarily, the string theory landscape imposed upon the inflationary framework is the highest-profile dimensionally connected multiverse model, though properly speaking the model is tiered. (It is not solely dimensionally connected, but rather it contains a dimensionally connected tier.)

As with Vilenkin's proposal, the model contains a tier of miniverses which are spatially extended from each other (emerging from inflation), but within each of the spatially extended miniverses, string theory contributes the novel component that generates the dimensionally connected tier. String theory's "landscape" concept does the bulk of the work.

[32] Knobe, Olum, & Vilenkin (2006), pp. 50-51.

Once string theory is coupled with the inflationary framework, a subtle—but importantly crucial—adjustment is assumed concerning the construction of each of the spatially extended miniverses, which are the "bubbles" arising from the strictly inflationary scenario. Those miniverses are spatially extended from each other. However, the extra dimensions assumed by string theory make a classificatory difference *within* each of the "bubble" miniverses. This is so because string theory dictates a mechanism by which the constants (such as the cosmological constant, which is the most commonly discussed) vary from miniverse to miniverse. The mechanism requires that each miniverse is comprised of eleven dimensions.[33] Within a single 11-dimensional miniverse, a separate dimensionally connected tier of miniverses emerges, as Susskind explains:

> Most string theorists think we really do live on a brane-world, floating in space with six extra dimensions. And perhaps there are other branes floating nearby, microscopically separated from us but invisible (to us) because our photons stick to our own brane, and theirs stick to their brane. Though invisible, these other branes would not be impossible to detect: gravity, formed of closed strings, would bridge the gap.[34]

Each of the branes (within an 11-dimensional miniverse) itself represents a miniverse. This is where the dimensionally connected tier arises. Because the branes are all embedded within the same 11-dimensional spacetime, some distance along one of the shared dimensions is guaranteed to separate each brane from each other brane. Even so, as Susskind hints at in the passage above, branes may be invisible to each other; the three spatial dimensions generating our brane (the universe) may differ, for example, from the three spatial dimensions generating a neighboring brane (another miniverse in the dimensionally connected tier). Crucially, however, our universe and the neighboring miniverse are separated from each other along at least one of the other four spatial dimensions. This is precisely the stipulation that characterizes a dimensionally connected tier of miniverses. Greene leaves little to interpretation concerning the dimensional connection between miniverses:

> The multiverses we've so far encountered, however different in detail, share one basic trait…the other universes are all "out there" in space. For the Quilted

[33] Again, keep firmly in mind the tiered structure. One tier—that referenced here—involves miniverses spatially extended from each other. The other tier—to be discussed imminently—involves miniverses dimensionally connected to each other.

[34] Susskind (2005), p. 283. The reader may have noticed that the spacetime dimensions were listed as totaling 11 in the sentences leading up to the Susskind passage, yet Susskind refers to a total of 10 spacetime dimensions in the passage itself. See Greene (2011), p. 112 for clarification about how one of the spatial dimensions needed for the theory was "missed" until recently.

> Multiverse "out there" means very far away in the everyday sense; for the Inflationary Multiverse it means beyond our bubble universe and across the rapidly expanding intervening realm; for the Brane Multiverse it means a possibly short distance away but the separation is through another dimension.[35]

Greene's "Brane Multiverse" is the model under present discussion. His description matches precisely the parameters of the dimensionally connected multiverse. Thus, the tier of n-dimensional brane miniverses (where $n < 10$) is a dimensionally connected tier of miniverses.

Leading proponents of the dimensionally connected multiverse in the contemporary era, as discussed, include Susskind and Greene. Joining them is Linde, whose aforementioned model likewise incorporates the string theory landscape (and hence exhibits a companion tier that is spatially extended).[36] Additional models classified in the dimensionally connected class include the strictly dimensionally connected Randall-Sundrum model and the Steinhardt-Turok model, which also includes a temporally extended tier.[37]

The dimensionally connected class is the sole class in which there are no corresponding historical models. In that sense, one might be tempted to claim that this class lacks connection to the tradition, which may in turn weaken the case that there exists a proper tradition at all. A rebuttal is readily available, however: this class is largely dependent upon the other classes because nearly all of the models residing in this class are tiered.[38] These models are not describable *solely* in a dimensionally connected way. This guarantees a connection to the other classes and further tightens the bond between this novel form of contemporary thought and the other historically grounded classes.

5.6 Dimensionally Separated Multiverses

The dimensionally separated category receives the least attention in the present project. The reason for this is that models embracing dimensional separation, strictly speaking, fail to satisfy the

---

[35] Greene (2011), p. 119. Note that Greene contributes to the tradition yet another idiosyncratic set of terminology; he names specific models, whereas the classification system introduced in Chapter 4 denotes models by type. Hence what he refers to as the Quilted Multiverse and the Inflationary Multiverse both, by present methods, fall under the spatially extended class, since both models involve miniverses separated by distance in the spatial dimension.
[36] See the corresponding footnote in the spatially extended section (Section 5.1) for references to Linde's relevant works.
[37] See Randall & Sundrum (1999) for details of their model. The Steinhardt-Turok model received attention in the section dedicated to temporally extended models (Section 5.3).
[38] Of the models referenced, only the Randall-Sundrum model avoids the use of multiple tiers of miniverses.

requirements of the multiverse that were set forth in Chapter 1. Miniverses that are dimensionally separated from each other are not topologically connected to each other, so they fail condition (i).

However, there still remain three good reasons for including mention of dimensionally separated multiverses within the tradition. The first was noted when the category was introduced in Chapter 4: simply relaxing the "topologically connected" desideratum (condition (i)) allows the dimensionally separated models to satisfy the remaining criteria, so prudence suggests that they be included, if only as a placeholder, for scholars who wish to investigate models of this sort within the multiverse context.

Secondly, many scholars *do* consider dimensionally separated models to be multiverse models.[39] Outwardly ignoring such models could be viewed as an inherent incompleteness in the proposed classification system. Instead, the simple solution is to mention the dimensionally separated class, but likewise to allocate more attention to the other multiverse classes.

Thirdly, and most importantly, the implementation of tiers makes this category all but essential to the classification scheme. Models such as Vilenkin's demonstrate the necessity: recall that his model is two-tiered, with one tier being spatially extended and the second tier being dimensionally separated. Without the explicit mention of the dimensionally separated class, Vilenkin's model would be misconstrued (by omitting the dimensionally separated portion) or omitted entirely from the tradition. Neither option seems preferable to simply including the dimensionally separated class (while at the same time outwardly emphasizing the fact that it does not straightforwardly fit the parameters of the multiverse that were outlined in Chapter 1).

With those caveats in place, and in keeping with the format of this section, I will mention only the most widely acknowledged model in this class, which belongs to Everett. His many-worlds quantum mechanics exactly fits the dimensionally separated class. An observation of some measurement invokes a "split" wherein one version of the observer witnesses one of the two (for simplicity's sake) possible outcomes and another version of the observer witnesses the other possible outcome. The two versions of the observer exist in separate miniverses—they have absolutely no access to each other—and there is no dimension along which one is separated from the other.[40]

---

[39] For example, the frequent labeling of many-worlds quantum mechanics as a "multiverse" necessitates the mentioning of this category within the project.

[40] Interestingly, it appears as though the two versions of the observer continue to experience the "same" spatial and temporal dimensions, since initially each experiences the same thing apart from the differing observation. This

Everett's model holds further importance for the present study. It is the model considered by Carter in his notorious work on the anthropic principle, which means that it factors in the discussion pertaining to typicality assumptions.[41]

As mentioned, the only cross-listed contemporary model is that proposed by Vilenkin (whose model also includes a spatially extended tier and (arguably) a temporally scaled tier). From the historical writers, only Boscovich in the modern era discusses a dimensionally separated model.

would seem to satisfy the parameters of the dimensionally connected class. Alas, Everett's model does not include any provision that describes the observers as separated by some distance along a non-spatial, non-temporal dimension, meaning the versions of the observer really are dimensionally separated.

[41] See Carter (1974), p. 298 for his endorsement of Everett's interpretation of quantum mechanics.

5.7 Summary

The multiverse tradition is historically rich and worthy of analysis. Even through adding only the models from the contemporary era that are discussed in this chapter, a list to which many more thinkers can be added in future development, the tradition is quite extensive:

Separation Type					
Temporally		**Spatially**		**Other (Dimensionally)**	
Extended	*Scaled*	*Extended*	*Scaled*	*Separated*	*Connected*
Anaximander Heraclitus Empedocles Hume Kant[1] Nietzsche Tolman Wheeler Landsberg & Park Baum & Frampton[1] Steinhardt & Turok[1]	Boscovich[1,2] Vilenkin[1]	Leucippus Democritus Diogenes Epicurus Lucretius Cusanus Palingenius Gilbert Bruno More Cavendish[1] Huygens Wright Kant[1] Boltzmann Vilenkin[1] Ellis & Brundrit Gott Sato, *et al.* Baum & Frampton[1] Linde[1] Susskind[1] Greene[1]	Cavendish[1] Pascal Boscovich[1,2] Whitehead Fournier d'Albe Charlier de Vaucouleurs Smolin	Boscovich[2] Everett Vilenkin[1]	Susskind[1] Linde[1] Randall & Sundrum[1] Steinhardt & Turok[1] Greene[1]
Notes: 1—Tiered multiverse 2—Multiple models proposed					

Figure 8: Thinkers in the multiverse tradition

The two prerequisites necessary to solidify the multiverse concept as a tradition fit for philosophical analysis have thus been met. A single classification scheme (as developed in Chapter 4) accounts for each of the possible multiverse configurations by breaking the possibility space into distinct categories. Secondly, the classification scheme displays continuity throughout the historical corpus of thought. This is necessary, since without the continuity there would be no guarantee that the concepts and problems encountered in one era matched the concepts and problems encountered in another. Chapters 2 and 3, in addition to the present chapter, demonstrate the continuity: each category of the classification scheme contains models from multiple eras.[42] The continuity demonstrated here from the ancient era through the modern era to the contemporary era concerning multiverse thought firmly establishes the multiverse tradition. Recognizing the tradition offers the opportunity for philosophical investigation at a deeper level than can be achieved without the recognition of the historical corpus. It is to this philosophical investigation that we now turn.

[42] The sole exception is the dimensionally connected class, but the primary objection surfacing from this fact was addressed in the previous section.

6
The Pillars of Multiverse Argumentation

With the historical reach of multiverse thought established and a full arsenal of models available for selection, philosophical analysis can begin. Attention shifts from *whether* the multiverse has been proposed historically to *why* the multiverse has been proposed historically. The existing literature contains no established, clearly articulated compendium of argumentation for multiverse thought, since each model's author is concerned only with establishing a proper argument for his or her specific model.

These individual pieces of argumentation will not suit the more ambitious scope desired for the current project. Instead, the task will involve carving out well-established *classes* of argumentation within the multiverse tradition. This will permit the distilling of particular arguments into their more general argument forms, from which broader philosophical implications can be derived. So, presently, we seek these "pillars" of multiverse argumentation.

Recall that, when treating of specific classes of multiverse models, there were incomplete schemes proposed by Oresme, Gale, Tegmark, and Trimble for classifying the models. Those incomplete proposals served collectively as the initial template for the full system laid out in Chapter 4. The same approach will be championed in the present chapter: some preexisting, loosely targeted thoughts about the matter from the literature will serve as a base from which a clear, distinct set of argument types will emerge. The present project cannot hope to accommodate the separate argumentation for each of the many, many models thus far encountered. Instead, it will be satisfactory to acquire a sound foundational structure of argument types. Accordingly, we will focus on the clearest and nearest-to-complete examples of multiverse argumentation in order to display the separate extant types.

The details for each of the three types of multiverse argumentation will be clarified within the following sections in this chapter. To illustrate the present state of the multiverse literature, I wish briefly to consider one recent account owing to Carr and Ellis.[1] There, in a multiverse "peace

[1] Carr & Ellis (2008).

summit" of sorts, Carr and Ellis present the basics of the cases (respectively) against and for the multiverse. Though the work is a popular account, it nonetheless serves nicely for present purposes because it is one of the rare publications that successfully captures each of the three pillars of multiverse argumentation (rather than mistakenly advocating only a single argumentative structure to multiverse thought). But it also typifies all that is currently lacking in multiverse analysis, as each piece of argumentation, haphazardly, is given only the briefest bit of attention by the authors. The procedure is so cursory that the specific foci of multiverse argumentation for each of the argument types gets muddled and mixed among the three pillars to be outlined momentarily. Before arriving there, first consider the seven "bones of contention" upon which Carr and Ellis build their respective cases:

1. There are plausibly galaxies just beyond the visual horizon, where we cannot see them, so we can extend this argument, step by step, to way beyond the horizon and infer that there are many different universes that we cannot see…
2. The existence of a multiverse is implied by inflation, which is verified by the Cosmic Microwave background anisotropy observations. In particular, known physics leads to chaotic inflation and this implies a multiverse…
3. The multiverse idea is testable, because it can be disproved if we determine there are closed spatial sections in the universe (for example, if the curvature is positive)…
4. The existence of a multiverse is the only physical explanation for the fine-tuning of parameters that leads to our existence…
5. The existence of a multiverse is implied by a probability argument: the universe is no more special than it need be to create life. In particular, the small value of the cosmological constant shows that other universes exist…
6. Even if one does not accept inflation, multiverses are predicted by many theories of particle physics…
7. The nature of science changes, so what is illegitimate science today may be legitimate tomorrow.[2]

This menagerie of multiverse thought—scattered as presented, but each perhaps a nascent version of a full argument—is representative of the range of subjects tied to the current multiverse literature. What will become solidly confirmed through historical augmentation via the works previously discussed in Chapters 2, 3, and 5 is that the three hallmark forms of multiverse argumentation are hidden among these "bones of contention."

In particular, the first "bone of contention" hints at an inductive type of argument for the multiverse. The second, fifth, and sixth "bones" hint at an implication-of-theory type of argument for the multiverse. The fourth hints at an explanation type of argument for the multiverse. These

[2] Carr & Ellis (2008), pp. 2.33-2.35.

three types roughly correspond to the three pillars of multiverse argumentation. (Note that the third and seventh "bones" address whether multiverse theories should be considered scientific. This, essentially, is a discussion about science and its denotation. Thus, those "bones" do not properly represent pieces of multiverse argumentation; they are pieces of science argumentation.) Without well-established, full forms of the argument types in question, there is no firm ground to stand upon for assessing whether the specific contentions by Carr and Ellis succeed for one side or the other. What follows is an extraction of those argument types.

We now return to the historical models and their accounts in order to establish the three pillars of multiverse argumentation.

6.1 Implication of Theory

Argumentative grounds for postulating a multiverse often emerge as implications of deeper theoretical assumptions. These theoretical assumptions can take theological form (as often occurs with older multiverse models) or they can take scientific form (as often occurs with newer multiverse models).[3] In either case, it is the deeper theoretical assumptions that propel the argument toward the multiverse conclusion.[4] It is the simple fact that the underlying assumption is deeply rooted, and not the content of the assumption itself, that generates the argument form. Thus, theological assumptions (usually in the form of teleology) and scientific assumptions can result (independently) in the same overall form of argumentation; the teleological argument is available in varying forms from many thinkers, and it is not so different at its core from the

[3] In the interest of simplicity, here the "scientific" form will take precedence. However, the teleological form is prevalent. Here are two examples: the first is included in More (1646), p. 15. There, in stanza 58, he intimates that the stars would not be so large if their only purpose was to be lights in our night sky. That purpose could be served with much smaller stars. Thus, argues More, we should conclude that they serve a purpose beyond simple lights in the night: they must be suns for other miniverses. This would give purpose to their size. We will see more of More's multiverse argumentation in Section 6.2, since he generates one of the noteworthy accounts of inductive multiverse argumentation. The second teleological example comes from Wright (1750), where More's point is argued even more forcefully: the stars have purpose, and that purpose is to display clearly God's creation of "an infinite shapeless Universe, crowded with Myriads of glorious Worlds" (p. 33).

[4] For a not-fully-developed instance of theory informing conclusions, see Digges (1576). There, he does not offer a multiverse directly, but he does offer insight into reasoning from physical theory. He argues that each planet must have a different center about which it orbits, because the planets are sometimes nearer and sometimes further away from Earth. This means that we should reject the Aristotelian contention that there is only a single center, and with that out of the way, the path is clear for one to maintain that the Earth is not lying at that single center. Multiverse argumentation of this sort will be the focus in this section.

scientific-theoretical premises that fortify some contemporary versions of multiverse argumentation. For this reason, the two types of argumentation are classified together.

The earliest forms of argumentation for the multiverse include premises that emerge directly from the parameters of the physical theory espoused by the theorist. Consider, once more, the reasoning expressed by Lucretius en route to his multiverse:

> In all dimensions alike, on this side or that, upward or downward through the universe, there is no end…Granted, then, that empty space extends without limit in every direction and that seeds innumerable in number are rushing on countless courses through an unfathomable universe under the impulse of perpetual motion, *it is in the highest degree unlikely that this earth and sky is the only one to have been created* and that all those particles are accomplishing nothing. This follows from the fact that our world has been made by nature through the spontaneous and casual collision and the multifarious, accidental, random and purposeless congregation and coalescence of atoms whose suddenly formed combinations could serve on each occasion as the starting-point of substantial fabrics—earth and sea and sky and the races of living creatures. On every ground, therefore, you must admit that there exists elsewhere other congeries of matter similar to this one which the ether clasps in ardent embrace.
>
> When there is plenty of matter in readiness, when space is available and no cause or circumstance impedes, then surely things must be wrought and effected. You have a store of atoms that could not be reckoned in full by the whole succession of living creatures. You have the same natural force to congregate them in any place precisely as they have been congregated here. You are bound therefore to acknowledge that in other regions there are other earths and various tribes of men and breeds of beasts.[5]

This argument, quoted at length to eliminate any doubts about context, can be reconstructed explicitly, by filling in the gaps where applicable and using Lucretius's own words where possible, to reach the multiverse conclusion as follows:

1. Space is infinite.
2. Atoms are infinite in number.
3. Atoms naturally move perpetually throughout space.
4. If atoms naturally move perpetually throughout space, then our universe was generated by the chance congregation of the atoms which comprise it.
5. Our universe was generated by the chance congregation of the atoms which comprise it.
6. If space is infinite and atoms are infinite in number, then the process that created our universe generates other miniverses.
7. The process that created our universe generates other miniverses.
8. If other miniverses are generated, then the multiverse exists.

C. The multiverse exists.

[5] Lucretius (1951), pp. 91-92. A portion of this passage was also presented in Chapter 2. Italics in original.

Before distilling this argument into its general form, which reaches a multiverse conclusion via implication from theory, a further display of historical examples is in order.

Perhaps the deepest well of multiverse argumentation available from the modern era belongs to Bruno. The second dialogue of *De L'Infinito Universo et Mondi* deals extensively with many Aristotelian arguments against the possibility of the universe being infinite. Though Kargon argues that "Bruno was an atomist, and as such rejected the entire Aristotelian framework of explanation," careful consideration of Bruno's system of thought reveals that this is an overhasty appraisal.[6] Bruno, in fact, involves much of Aristotelian influence in his physical and cosmological works, and this directly informs his multiverse thought.

The Aristotelian influence is perhaps most evident in the third dialogue, when Bruno seeks to differentiate his system of physics from the Aristotelian doctrine. Though Bruno's intent is distance from Aristotle, there can be no question that the result is merely *distance from*, and not outright *rejection of*, the Aristotelian framework:

> For, as to motion, everything endowed with natural motion revolveth in a circle around either his own or some other centre. I speak of revolution, not having regard simply to the geometrical circle and circular motion, but according to that law which we observe to govern the physical changes in the position of natural bodies. Motion in a straight line is neither innate nor natural to any prime body… I deny not the distinction of the elements, for I leave everyone at liberty to distinguish as he pleaseth concerning natural things. But I deny this order, this disposition that the earth is surrounded and contained by water, water by air, air by fire, fire by heaven. Because I say there is but one single container that comprehendeth all bodies and those great frames which appear to us as scattered and sparse in this vast field, wherein every one of those bodies, stars, worlds and eternal lights is composed of that which is named earth, water, air and fire.[7]

Part of the argumentative import of this passage resides in the fact that it is not coming from Philotheo, the voice of Bruno in the dialogue. Rather, it comes from Fracastoro, the character thought to have been named after the colleague of Copernicus.[8] Fracastoro represents the 'intelligent but uncommitted' interlocutor in the dialogue—interested in the discussion, but not committed to either of the competing positions at the outset. Fracastoro has been instructed by Philotheo to reply to Burchio, who plays the role of the dogmatic Aristotelian, concerning the material composition of the stars. Thus, from the reader's perspective, we see Bruno expressly

[6] Kargon (1966), p. 9. See also p. 11, where Kargon claims that "he [Thomas Hariot] followed Bruno's dictum and sought the key to all explanation, mathematical as well as physical, in atomism."
[7] Bruno (1950), p. 314.
[8] See Singer (1950), p. 68.

entrusting the explication of his physics to the perceptive scholar who, educated in the Aristotelian system, makes alterations to the system but does not break completely from it.

Furthermore, the atomistic influences in Bruno's cosmological writings are readily apparent. He writes, regarding the composition of the innumerable worlds (miniverses), that

> The universe being infinite, and the bodies thereof transmutable, all are therefore constantly dispersed and constantly reassembled; they send forth their substance, and receive within themselves wandering substance.[9]

This is pure atomistic doctrine, through and through, passed down from Epicurus by way of Lucretius to Bruno. Yet despite this core of atomism, Bruno's sympathy toward some of the Peripatetic premises lands him squarely in neither the atomistic nor the Aristotelian camp, but rather somewhere between. Most importantly, his hybrid system of physics puts at his disposal the necessary tools of argumentation to combat the long-standing Aristotelian objection to the possibility of the existence of multiple miniverses, which relies upon natural motion (of the Aristotelian type) and the existence of a center of the universe to orient that natural motion.

Bruno resolves the discord between the Aristotelian universe hypothesis and his own spatially extended multiverse hypothesis by harnessing the distinction between the two theories with respect to the concept of natural place. The simple dispersion of the "central point" subtly impacts the denotation of "natural motion." And with the adjusted meaning of "natural motion" at his disposal, Bruno constructs a multiverse from the Aristotelian universe. All of this flows from Bruno's underlying assumptions about physics.

In explicit form, Bruno's argument for the multiverse looks thus:

1. Circular motion around some center is natural motion for all natural bodies (earth, air, fire, and water).
2. Space is infinite.
3. If space is infinite, there is not a single center controlling natural motion.
4. There is not a single center controlling natural motion.
5. If there is not a single center controlling natural motion and circular motion is natural motion for all bodies, then separate miniverses of congregated earth, air, fire, and water form.
6. If separate miniverses form, then the multiverse exists.

C. The multiverse exists.

[9] Bruno (1950), p. 284.

As expected, Bruno adopts premises from both the atomistic and Aristotelian legacies within his argument. These theoretical assumptions combine to imply (within his system) that the multiverse exists.[10]

Before shifting to a contemporary example of multiverse argumentation via theoretical implication, a small digression is in order. An interesting case for comparison between the ancients and the contemporaries involves the role of observational evidence. The ancients—particularly the atomists—disregard evidence from the senses as illegitimate, whereas evidence obtained through the intellect is to be considered legitimate.[11] This may go some way toward explaining why there was little (perhaps no) opposition to the multiverse on grounds of unobservability at the time, whereas unobservability is of widespread concern among contemporary thinkers.

Bruno joins the ancients in eschewing sensory input in favor of intellectual considerations. In *De L'Infinito Universo et Mondi*, he writes:

> No corporeal sense can perceive the infinite. None of our senses could be expected to furnish this conclusion; for the infinite cannot be the object of sense-perception; therefore he who demandeth to obtain this knowledge through the senses is like unto one who would desire to see with his eyes both substance and essence….It is the part of the intellect to judge, yielding due weight to factors absent and separated by distance of time and by space intervals.[12]

Bruno rejects the longstanding Aristotelian assumption that the universe is finite, and accordingly he asserts his premise (2) from the above argument reconstruction. In Bruno's estimation, only one's intellect can provide justification for theorizing about what lies beyond the domain of observation. While modern approaches to cosmology recognize that the universe need not be infinite for there to be observationally inaccessible regions, Bruno's insight is well taken: if one postulates observationally inaccessible regions, then one is forced to invoke other (non-observational) means of theorizing, such as one's intellect, concerning such regions. This sort of theorizing, which was at one point the hallmark of proper scientific reasoning, now treads on the

---

[10] Similarly to what Bruno demonstrates here, Campanella (in Campanella (1937)) argues that the dismantling of the Aristotelian theory by allowing the four elements to exist in the celestial realm would thereby result in the multiverse. Originally, this appears as a statement of an "accusation" against Galileo (p. 8), to which Campanella replies on pp. 64-67. He does not argue straightforwardly for his own belief in the multiverse, but rather he defends the assertions of Galileo; the important point here is the existence of multiverse argumentation on the grounds of theoretical assumption.

[11] See, for example, the claim from Democritus that "there are two kinds of knowing, one through the senses and the other through the intellect. Of these…the one through the intellect [is] 'legitimate'…and that through the senses [is] 'bastard'." (Kirk, Raven, & Schofield (1983), p.412. Bracketed additions inserted for clarity.)

[12] Bruno (1950), p. 250-251.

fringe of acceptable practice. In any era, however, theorizing of this sort is heavily tied to the use of typicality assumptions, which will receive attention in Chapters 7 and 8.

Turning now to an example of contemporary multiverse argumentation, we find Vilenkin (and co-authors Knobe and Olum) arguing for a spatially extended multiverse. They write:

> Suppose we pick a region of space and an interval of time. This defines a region of spacetime. We want to consider histories that can occur in this spacetime region. If we divide the space in such a region into small subregions, we can define a history as a specification of the contents of each subregion at successive moments of time. Quantum mechanics assigns a probability to each of the histories, and we say that a history is possible if its probability is not equal to zero…If the subregions and their values are specified sufficiently coarsely, the resulting histories will decohere, meaning that they do not interfere with each other and can meaningfully be interpreted as classical alternatives…The claim that the universe is infinite is a consequence of the theory of inflation…False vacuum decay is a probabilistic process; it does not occur everywhere simultaneously. In practically all models of inflation, false vacuum regions grow due to expansion faster than decay. This means that the total volume of such regions in the universe keeps growing without bound…Since the universe is spatially infinite, it can be subdivided into an infinite number of regions of any given size. Thus we have an infinite number of regions and only a finite number of histories that can unfold in them. Since the regions develop independently, every possible history has a non-zero probability and will therefore, with probability 1, occur in an infinite number of regions.[13]

As was done with the arguments from Lucretius and Bruno, this argument can be deconstructed into its explicit formulation. Accordingly:

1. Inflationary cosmology is true.
2. Quantum mechanics defines a finite set of decoherent histories within any region of spacetime.
3. Each region of spacetime develops independently.
4. Every possible history has a non-zero probability of occurring.
5. If inflationary cosmology is true, the universe is spatially infinite.
6. If the universe is spatially infinite, it can be subdivided into an infinite number of finite regions.
7. The universe can be subdivided into an infinite number of finite regions.
8. If quantum mechanics defines a finite set of decoherent histories within any region of spacetime, then the number of possible histories that can unfold in any given region is finite.
9. The number of possible histories that can unfold in any given region is finite.
10. If the universe can be subdivided into an infinite number of finite regions, and the number of possible histories that can unfold in any given region is finite, and every possible history has a non-zero probability of occurring, then every possible history occurs in an infinite number of regions.

[13] Knobe, Olum, & Vilenkin (2006), pp. 49-51.

11. If every possible history occurs in an infinite number of regions, then the multiverse exists.

C. The multiverse exists.

We thus see clear examples of explicit argumentation for the multiverse in each of the three historical eras. Each of the arguments attempts to establish the existence of the multiverse—in each of these cases, a spatially extended multiverse—via implication from underlying scientific assumptions. What remains is to extract the general form of these arguments in such a way as to unite them explicitly; achieving this will successfully capture the likeness between the arguments.

To begin, note that each argument starts with a clear statement of the underlying physics to which the author subscribes. For Lucretius, this is represented in premises (1)-(3). For Bruno, it is represented in premises (1) and (2). For Vilenkin, it is represented in premises (1)-(4). This step is unsurprising, since these arguments are presented together in this section specifically because they all involve underlying theoretical assumptions in arguing for the multiverse. Thus, in accordance, we see that a necessary piece of this pillar of multiverse argumentation involves

(i) Assumed physics.

A note for clarification: the label "physics" is used strictly because the previously mentioned sister argument, which involves theology (typically in the form of teleology) is not the focus here. A multiverse argument that employs an underlying assumption of teleology in place of physics would proceed in similar fashion, with "teleology" replacing "physics" in (i).

Next, note that each of the displayed arguments proceeds to investigate the implications associated with the assumed physics. Sometimes (as with Lucretius), this involves straightforwardly reasoning through the implications of the underlying physics. Sometimes (as with Bruno), this involves noting the consequences of changing a previously held assumption. Sometimes (as with Vilenkin), this involves synthesizing assumptions from specialized fields of physical study that may not have been taken together previously. In any case, the result, in terms of multiverse argumentation, is the creation of some mechanism whereby miniverses (and hence the universe) are generated. For the remainder of the project, I will refer to this mechanism as the *miniverse generation mechanism*. Lucretius develops a miniverse generation mechanism in premises (4)-(7). Bruno does so in premises (3)-(5). Vilenkin follows suit in premises (5)-(10). The general logical structure of what these authors convey can be captured as

(ii) If assumed physics, then the miniverse generation mechanism exists.

The concept of a miniverse generation mechanism is extremely important. In Chapter 8, the reason will become clear: the miniverse generation mechanism is the vehicle within which typicality assumptions are introduced into multiverse argumentation in implication-of-theory arguments of the sort under consideration here.

The remaining steps are fairly straightforward, since conveying the physics and then inferring the miniverse generation mechanism are the (potentially) troublesome steps. The argument's form is rounded out with generally non-contentious premises (iii) and (iv):

(iii) If the miniverse generation mechanism exists, then more than one miniverse exists;
(iv) If more than one miniverse exists, then the multiverse exists.

These two premises, because they are so innocuous, are often left implicit; this is especially true of (iv).

In sum, then, the pillar of multiverse argumentation dealing with the implication of theory takes the following form:

(i) Assumed physics.
(ii) If assumed physics, then the miniverse generation mechanism exists.
(iii) If the miniverse generation mechanism exists, then more than one miniverse exists.
(iv) If more than one miniverse exists, then the multiverse exists.
C. The multiverse exists.

The specific arguments put forth by Lucretius, Bruno, and Vilenkin all are instantiations of this general argument form.

6.2 Induction

The first explicitly formulated piece of induction-centered argumentation for the multiverse is provided by More. Motivated to combat the atheistic tendencies of some of the more radical atomists, More aims to make compatible theistic belief and atomism.[14] However, this very goal impairs More's ability to employ the standard atomistic arguments for the multiverse, because precisely those standard atomistic arguments are what generate the accusations of atheism: a world created of bare chance and incorruptible atoms leaves no room for a deity.[15] Thus, we see More

[14] See Kargon (1966), p. 83-86.
[15] Recall from the previous section that when both space and the number of atoms are infinite, the atomists argue that the chance interaction of atoms each obeying the same principles of motion generate the separate miniverses that collectively comprise a multiverse.

appeal to argumentation for the multiverse on grounds separate from the physical theory he espouses. In his *Democritus Platonissans*, he writes:

> We may conclude; as well as men conclude
> That there is aire farre 'bove the mountains high,
> Or that th' Earth a sad substance doth include
> Even to the Centre with like qualities indu'd.
> For who did ever the Earths Centre pierce,
> And felt or sand or gravell with his spade
> At such a depth? what Histories rehearse
> That ever wight did dare for to invade
> Her bowels but one mile in dampish shade?
> Yet I'll be bold to say that few or none
> But deem this globe even to the bottome made
> Of solid earth, and that her nature's one
> Throughout, though plain experience hath it never shown.
> But sith sad earth so farre as they have gone
> They still decrie, eas'ly they do inferre
> Without all check of reason, were they down
> Never so deep, like substance would appear,
> Ne dream of any hollow horrour there.
> My mind with like uncurb'd facilitie
> Concludes from what by sight is seen so clear
> That ther's no barren wast vacuitie
> Above the worlds we see, but still new worlds there lie,
> And still and still even to infinitie.[16]

Though perhaps implicit within the musings of those writing before him, More is the first to explicitly appeal to this line of reasoning in argumentative fashion. Indeed, here is found an attempt at justification for the multiverse that lies outside of the theory of which it speaks. No appeal is made to the particular physics assumed by More; this is not the standard atomistic defense of the existence of other miniverses. Rather, More calls upon empirical induction.

In keeping with the structure introduced in Section 6.1, let us now recreate More's argument explicitly:

1. Observation has shown that, as deeply as anyone has ever dug into the Earth, what exists there is similar to the material at the surface of the Earth.
2. One should maintain that going even deeper into the Earth would yield observations that match what has already been found.
3. Likewise, one should maintain that as-yet-uncollected observations in general will yield a match with already-collected observations.

[16] More (1646), p. 16-17 (Stanzas 61-64).

4. Observations of other miniverses (beyond our own universe) have been collected.[17]
5. Miniverses exist beyond what can be observed.
6. If miniverses exist beyond what can be observed, then the multiverse exists.

C. The multiverse exists.[18]

The third premise is critical for this study. It is the first explicit interaction with the Typicality assumption. After allusions and fleeting references, this staple of multiverse argumentation appears here first in explicit form.

A second case from the modern era is to be found in Wright's writings. Very much in line with More's reasoning, Wright argues that the evidence we have accrued can be brought to bear concerning what we should expect to observe (were we able) in the celestial domain:

> That the sidereal Planets are not visible to us, can be no Objection to their actual Existence, and being there, is plain from this; it is well known, that the Stars themselves, which are their Centeral, and only radiant Bodies, are little more to us at the Earth, than mathematical Points. How ridiculous then is it to expect, that any of their small opaque Attendance, should ever be perceived so far as the Earth by us; and besides, to show the Impossibility of such a Discovery, we need only consider, what is, and what is not to be expected, or known in our own home System. All the Planets in this our sensible Region, every Astronomer knows, is far from being visible to one another, in every individual Sphere; for to an Eye at the Orb of *Saturn*, this Earth we live upon, which requires Years to circumscribe, and Ages to be made acquainted with, and is far from being yet all known, cannot possibly from the above Planet be seen. And further, since *Saturn* and *Jupiter*, two of the most material and considerable Globes we know of, except the Sun himself, are Bodies apparently of the same kind, and are observed each to have a Number of lesser Planets moving round them; why may we not expect with equal Certainty and Propriety, that all other Bodies, under the same Circumstances, are in like manner attended; that is, seeing the Sun is found to be the Center of a System of Bodies, all variously volving round him?...Consequently (as you must perceive) no Arguments can possibly be drawn to deny the Existence of such Bodies, with any Shew of Reason, from their not having been seen by us.[19]

Wright's case, like More's, draws explicitly upon the Typicality assumption as a crucial piece to the argument. To see it in full:

[17] It is very important here to recall the previous discussion from Chapter 4 concerning the *concept* of causal disconnection versus the *definition* of causal disconnection. More claims in this premise that other miniverses have been observed, but that does not thereby break the dictum that miniverses (by nature) are causally disconnected. More's conception of causal disconnection implicitly allows observation.

[18] More, and others to follow, often do not explicitly state the conclusion as such. (Nor, of course, do they use language such as "multiverse.") In the interest of completeness for the arguments considered, I often add the implicit steps that are left out in the original versions.

[19] Wright (1750), pp. 34-35.

1. Observation has shown that, in our solar system, every planet is not visible to every other planet.
2. Nevertheless, planets that are not visible to us do exist.
3. Saturn and Jupiter—which had previously not been visible in detail—each have a set of bodies traveling around them, just as the sun does.
4. One should maintain that what we cannot observe is like what we can observe.
5. Other miniverses (similar to the sun and its planets, and Saturn and its planets, and Jupiter and its planets) exist in places we cannot observe.
6. If other miniverses exist in places we cannot observe, the multiverse exists.

C. The multiverse exists.

Premise (4) is the Typicality assumption, and it emerges in Wright's own words when he writes "we need only consider, what is, and what is not to be expected, or known in our own home System." As is becoming evident, typicality assumptions factor heavily in multiverse argumentation involving induction. Ultimately, this will manifest as a premise within the form of the argument that represents this pillar of multiverse argumentation.

A final example from the historical models comes from the contemporary era. Rees argues in line with More and Wright by claiming that what exists in unobservable regions matches what exists in observable regions. Pending a final verdict on whether expansion accelerates or decelerates, such regions may be permanently beyond observational reach:

> There is a limit to how far out into space our present-day instruments can probe. Obviously there is nothing fundamental about this limit: it is constrained by current technology…Even if there were absolutely no technical limits to the power of telescopes, our observations are still bounded by a horizon, set by the distance that any signal, moving at the speed of light, could have traveled since the Big Bang…When our universe is, say, twice as old as it is now, this horizon will be twice as far away. But if that expansion is decelerating, then each galaxy, having slowed down, will be *less than* twice as far away, so the horizon of our remote descendants will also encompass extra galaxies beyond our horizon today…Surely the longer waiting time is a merely quantitative difference, not one that changes the epistemological status of these faraway galaxies…but if the cosmic expansion is accelerating, we are now receding from those remote galaxies at an ever increasing rate, so if their light has not reached us yet, it never will. Such galaxies are not merely *unobservable in principle now*—they will be beyond our horizon *forever*. But if a galaxy is *now* unobservable, it hardly seems to matter whether it remains unobservable forever, or whether, as in a decelerating universe, it would come into view if we waited a trillion years…The never-observable galaxies [previously described] would have emerged from the same Big Bang as we did. But suppose that, instead of causally disjoint regions emerging from a single Big Bang (via an episode of inflation), we imagine separate Big Bangs. Are space-times that are completely disjoint from ours any less real than regions that never come within our

> horizon in what we traditionally call our own universe? Surely not. So these other universes should count as real parts of our cosmos, too.[20]

Rees goes a step further than More and Wright in that he extends the scope of argumentation beyond spatially extended miniverses to dimensionally separated miniverses. For the sake of uniformity, let us reconstruct Rees's argument:

1. The horizon of observation is limited by the distance light has traveled since the Big Bang.
2. What lies outside the horizon of observation is like what lies inside the horizon of observation.
3. As the time since the Big Bang increases, cosmic expansion may either decelerate or accelerate.
4. If cosmic expansion decelerates, the horizon will encompass galaxies that previously were unobservable.
5. If cosmic expansion accelerates, the horizon will never reach galaxies that would become observable if expansion had decelerated.
6. Either way, such galaxies—whether unobservable only for the present or unobservable permanently—exist now.
7. Likewise, what occurs in places dimensionally separated from our universe is similar to what happened when our universe was created.
8. Other Big Bangs generate miniverses that are dimensionally separated from the universe.
9. If other Big Bangs generate miniverses that are dimensionally separated from the universe, then the multiverse exists.

C. The multiverse exists.

Note that Rees does not explicitly declare the Typicality assumption taken as premise (2) in the reconstruction, though without it his argument falls apart. It is implicitly assumed. Further, he actually employs the Typicality assumption twice, since it is needed once again (as premise (7) in the reconstruction) to connect the emergence of other miniverses to the emergence of our own universe; in neither case does Rees explicitly declare the Typicality assumption. This telling characteristic of typicality assumptions is problematic, as will be discussed in detail in Chapter 7.

With several examples of multiverse argumentation via induction now on display, the time has come to extract the general form of these arguments. It is quite evident that a typicality assumption will occupy one of the premise slots. Before that, however, notice that each of the authors of the inspected arguments places an initial emphasis on some aspect of observation, be it actually collected observations or the limits of potential observation. More does so in premises (1) and (4); Wright does so in premises (1)-(3); Rees does so in premises (1) and (3)-(5). Accordingly:

[20] Rees (2001), pp.167-169. Italics in original. Bracketed addition inserted for clarity.

(i) Actual or potential observation(s).

There is some question about whether "potential observation" really is nothing more than theory. For example, in Rees's argument, premises (3)-(5), which deal with the possible outcomes concerning the cosmic expansion, could be construed as bits of physical theory, which might tempt one to place arguments of this type into the "Implication of Theory" category rather than the "Induction" category. However, this temptation should be resisted for the simple reason that the material in an argument like Rees's deals explicitly with the actually accessible, whereas the material in an argument like Vilenkin's deals with theoretical components that contribute to a miniverse generation mechanism, a piece of theory that in principle lies beyond any possible observation. This is a crucial distinguishing feature.

With observational components in place, the theorists turn to their respective typicality assumptions. This assumption provides a link between what is (or can be) observed and what cannot be (or has not been) observed. Exploring the inner workings of typicality assumptions will be a focus in the remainder of this project. For now, however:

(ii) A typicality assumption.[21]

For More, the main typicality assumption he adopts comes in premise (3), though he has a smaller-scope Typicality assumption in premise (2) as well. For Wright, the Typicality assumption appears in premise (4). Likewise for Rees and his premises (2) and (7).

Finally, the remaining pieces of the arguments are filled out with premises that connect the observational and typicality assumption premises to the existence of the multiverse. See premises (5) and (6) in More's argument, premises (5) and (6) in Wright's argument, and premises (6), (8), and (9) in Rees's argument for these connecting pieces. In each respective argument, they contribute to the establishment of

(iii) If actual or potential observation(s) and typicality assumption, then other miniverses exist.

and

(iv) If other miniverses exist, then the multiverse exists.

[21] Recall the convention: "Typicality assumption" (capital "T") refers to the specific assumption that what cannot be observed is like what can be observed, whereas "typicality assumption" (lowercase "t") refers generically either to the Typicality assumption or to the Atypicality assumption. Thus, in the argument form, I am referring to the inclusion by the theorist of either the Typicality or the Atypicality assumption, since separate authors may use separate typicality assumptions in the construction of their arguments.

Collectively, the premises in the argument form combine to establish the multiverse conclusion as follows:

(i) Actual or potential observation(s).
(ii) A typicality assumption.
(iii) If actual or potential observation(s) and typicality assumption, then other miniverses exist.
(iv) If other miniverses exist, then the multiverse exists.
C. The multiverse exists.

Notice the crucial difference between this pillar of multiverse argumentation and the previous: this argument form need not commit one to any particular theory of physics, whereas the implication of theory argument form required explicit commitment to a physical theory in its premise (i). Indeed, we see More and Wright arguing in this fashion for the multiverse without committing (or even mentioning) a specific theory of physics. Rees does include cosmic expansion and Big Bang cosmology among his premises, though as discussed in the explication of (i), the inclusion of premises involving physical theory does not automatically indicate an argument structure that represents the implication of theory form; rather, the focus (or lack thereof) on observational premises appears to be the telling distinction between the two argument types.

It is worth recognizing the existence of a "pessimistic metainductive" version of the just-presented argument form. In this version, it is supposed that just as we once believed in a geocentric, then heliocentric, then galactocentric worldview, we should now realize that we were mistaken at each step. Through inductive inference, this should lead us to conclude that our universe likewise is not any sort of a central focus of existence, and hence that other miniverses exist.[22]

6.3 Explanation

Consider the following claim from Kragh concerning the general concept of the multiverse: "What used to be a philosophical speculation is now claimed to be a new paradigm in cosmological physics, meant to replace the traditional ideal of explaining the universe and what is in it in a unique way from first principles."[23] Likewise, Earman writes that

[22] See Carr & Ellis (2008), p. 2.36 and Carr (2007a) pp. 7-10 for two examples of this use of the inductive argument for the existence of the multiverse.
[23] Kragh (2011), p. 255.

> multiverse proponents proceed in three steps. First they feign puzzlement about some phenomenon, such as the fine tuning of parameters…Next they argue that the multiverse, usually in combination with a mild and unobjectionable form of the Anthropic Principle, resolves the puzzlement. And finally they conclude that they have provided a scientific explanation.[24]

The sentiments expressed by Kragh and Earman—neither of which are directly advocating nor denying the multiverse, but are merely reporting the intent of multiverse theorists—indicate that some multiverse arguments possess a likeness with each other in the sense that the multiverse's utility as a scientific explanation is the crucial feature.[25] This is the third of the three generally invoked means of multiverse argumentation: the multiverse is argued for via its explanatory capability.[26]

Because the crucial components for this type of argument for the multiverse are so succinctly expressed by Earman, the structure of investigation that was implemented in the previous two sections will be reversed: the general form for this type of argument for the multiverse will be revealed, and the remainder of the section will be dedicated to showing several instantiations of the form. Accordingly, the pillar of multiverse argumentation associated with scientific explanation:

(i). A cosmological explanandum requires an explanans.
(ii). *MULTIVERSE* provides the most appealing explanans. [27]
(iii). If *MULTIVERSE* provides the most appealing explanans, then the multiverse exists.
C. The multiverse exists.

As will be seen, Earman rightly identifies the fine tuning of the universe's parameters as the most frequently employed cosmological explanandum in (i). Additionally, (iii) clearly is closely akin to inference to the best explanation, so the vices and virtues of that approach almost certainly apply

[24] Earman (2009 ms.), p. 18.
[25] For other nearly identical accounts with respect to the claim that argumentation for the multiverse essentially comes down to arguing that it best explains our orderly universe, see (for example) page 487 of Davies (2007), Smith (1986), Hacking (1987), and Craig (1988).
[26] A discourse concerning precisely what variety of scientific explanation is adopted by multiverse theorists would take us too far afield. Instead, we will rely on Earman and Kragh as guides for developing the general argument schema: multiverse theorists implement the multiverse hypothesis in their efforts to scientifically explain some cosmological feature. A deeper analysis that pairs specific accounts of scientific explanation with specific pieces of multiverse argumentation is left for future research.
[27] Recall, from Chapter 1, the hypotheses *UNIVERSE* and *MULTIVERSE*; they will factor heavily in the ensuing analysis. *MULTIVERSE* is the hypothesis that our universe (and its combination of laws, parameters, and constants) is just one region within a spacetime structure that has the following features: (i) The spacetime structure is topologically connected; (ii) The spacetime structure contains many causally disconnected regions; and (iii) The causally disconnected regions may exhibit different combinations of laws, parameters, and constants. *UNIVERSE* is the hypothesis that the Universe contains the same combination of laws, parameters, and constants throughout its entirety.

to the following examples from the multiverse tradition; little attention will be directed toward those considerations. Instead, the bulk of the section will serve to display the variations on offer concerning the establishment of (ii) within the multiverse tradition.

To begin, first recall the model proposed by Empedocles in the ancient era. His is a temporally separated model wherein Love and Strife alternate in taking hold of the dominant position; when Love holds full sway, the four elements (earth, water, air, and fire) are maximally mixed within an elemental soup. When Strife holds full sway, the four elements are completely separated from each other into distinct layers of earth, water, air, and fire. The majority of the time, when neither Love nor Strife is maximal, varying degrees of biological organization are possible.[28] These are the parameters wherein Empedocles purports to gain justification for the multiverse model he creates.

In a translation of fragment 20, Empedocles writes:

> This (the alternation of increasing Love and Strife) is manifest in the frame of the human body. Limbs that in the peak of blooming life have found a body, at one time (i.e. during increasing Love) come together through Love to be all one. At another time (i.e. during increasing Strife) they are torn apart again (i.e. under increasing Strife so as to be in the same condition as they were before under increasing Love) by wicked spirits of dissension, and wander each of them apart along the breakers of life's shore. The same is true for bushes and for fish in water palaces, for beasts that sleep on the mountain side and pigeons that float on wings.[29]

It is difficult to reconstruct a full argument for Empedocles's multiverse model merely from the fragments we have remaining of his work, but there can be no question that this fragment aims at answering the questions associated with the appearance and contents of our universe. This nicely fits the parameters of (i).[30]

The elements of Empedocles's argumentation that are associated with (ii) and (iii) are straightforwardly identifiable, though in a fashion that is not clearly ostensibly attributable to a single passage, as in the case of (i). With respect to (iii), the very fact that Empedocles works to

[28] See chapters 7 and 9 of O'Brien (1969) for full details. O'Brien argues there that a proper interpretation of the physics and biology of Empedocles depends upon showing their interaction with respect to the different zoogonical stages of development within the history of the cosmos. This dovetails perfectly with the notion that Empedocles seeks to justify his multiverse cosmology by establishing its explanatory virtue, which is precisely what is under consideration here.
[29] O'Brien (1969), p. 227. Parenthetical expressions appear within O'Brien's text.
[30] Wright explicitly attributes the overall aim of explanation to Empedocles's writing in *Physics*. See p. 48 of Wright's introduction to Empedocles (1981). This provides direct support for interpreting the passage from Empedocles as an instantiation of (i).

establish his model, putting it forth as truth, implicitly indicates his conveyance of the premise. This is true of nearly all of the writers who argue under the explanatory pillar, as will become apparent.

With respect to (ii), the chief evidence comes in the form of an argument against (or perhaps building upon) other offerings. In doing so, Empedocles attempts to convey that his temporally separated multiverse is more appealing—with respect to explaining the universe—than other cosmological theories on offer. One such allusion to this overture comes in fragment 39, where Empedocles writes "If the depths of earth, and extensive air, are without limit, as has come foolishly from the tongue of the mouths of many who have seen but little of the whole".[31] The fragment lives up to its billing (in its incompleteness), but it likewise communicates the intention of establishing the temporally extended model as the most appealing available theory when compared to the "foolishness" of the other available offerings. Furthering this notion, Wright assesses the fragments of Empedocles's *Physics* as follows:

> In sum, Empedocles attributed to his four roots the spatial and temporal continuity, the changelessness, and the homogeneity of Parmenides' *ὄν*. Taking this as his starting point he then set out to explain everything perceptible to the senses as an arrangement of parts of these roots, in which the proportion of the parts accounts for the perceived characteristics.[32]

This succinct pair of sentences from Wright aptly captures the presence of (i), (ii), and (iii) in Empedocles's work, but it especially highlights the means by which Empedocles targets the establishment of (ii). Empedocles believed that his temporally extended multiverse model could provide the most appealing explanans for what the universe's observers actually observe.

A shift away from the ancient era does not diminish the presence of arguments for the multiverse by way of explanation. As first flagged in Chapter 3, Hume's argumentation has as its centerpiece a reliance on the explanatory benefit of the multiverse. A continuation of the passages provided there reveals Hume's argumentative position. It lies fully in line with the argument form to which this section is dedicated. Concerning his temporally extended model—his "revived" Epicurean multiverse—Hume writes:

> Thus the universe goes on for many ages in a continued succession of chaos and disorder. But is it not possible that it may settle at last, so as not to lose its motion and active force (for that we have supposed inherent in it), yet so as to preserve an uniformity of appearance, amidst the continual motion and fluctuation of its parts?

[31] Empedocles (1981), p. 199.
[32] Empedocles (1981), p. 30.

> This we find to be the case with the universe at present. Every individual is perpetually changing, and every part of every individual, and yet the whole remains, in appearance, the same. May we not hope for such a position, or rather be assured of it, from the eternal revolutions of unguided matter, and may not this account for all the appearing wisdom and contrivance which is in the universe? Let us contemplate the subject a little, and we shall find, that this adjustment, if attained by matter, of a seeming stability in the forms, with a real and perpetual revolution or motion of parts, affords a plausible, if not a true solution of the difficulty.[33]

Hume proceeds to expand this argumentation for the multiverse as a means of explaining the present order in the world. With the continual and eternal exchange of matter generating miniverse after miniverse, the present orderliness and stability of the universe surfaces during some duration of time.

We thus see all three critical components within Hume's argument. The fact that some explanandum is sought does not appear until the closing line of the paragraph, but that line readily identifies the orderliness of the universe as something in need of explanation. And it is very clear that he has no problem with the conditional statement that comprises (iii), for reasons very similar to what surfaced with Empedocles: the very search for the best explanation that Hume undertakes in the work suggests that the best explanation is the one with which he should associate truth (and existence). If it were possible to establish that the temporally extended multiverse succeeded where others failed to explain, then Hume would affirm that the dominance of his multiverse model with respect to explanation means that the multiverse exists.[34]

Only context reveals that Hume means to advance a claim akin to (ii) for the purposes of the argument he constructs. In actuality, Hume *denies* (ii). But this denial comes outside of the argument itself that he puts forth in this portion of his work.[35] For the purpose of the argument—as evidenced by the passage itself—Hume indicates that the temporally extended multiverse can do the explaining that the intelligent design hypothesis does, but without the deity, thereby making it superior. This is precisely what (ii) conveys (when adjusted for context).

---

[33] Hume (1947), pp. 184-185.

[34] For the sake of thoroughness, it should be noted that Hume closes this section of his work by admitting that neither his thesis nor the intelligent design thesis gains an upper hand on the other. His aim is merely to note that *there are* alternative arguments that could be put forth. This does not diminish the importance of Hume's argument for present purposes, however, because the goal here is to demonstrate that the multiverse argument associated with explanation recurs throughout the multiverse tradition, thus qualifying it as a pillar of multiverse argumentation. Nor should we assume that the lack of final committal to one side or the other means that Hume rejects (iii), because (iii) is needed for the argument to succeed regardless of Hume's final acceptance or refusal of it.

[35] See the previous footnote.

In the contemporary era, multiverse argumentation emphasizing explanation has flourished to the point that many (such as Earman and Kragh, in the passages opening this section) maintain explanation as *the* argument for the multiverse. The previous two sections have demonstrated otherwise, but nevertheless, there can be no doubt that explanation plays a prominent role in very many contemporary multiverse arguments.

One example, noted briefly in Chapter 5, is the argumentation woven into Tolman's description of his temporally extended multiverse. In the passage cited there, his most noteworthy argumentation includes the claim that the first of the two models he considers "has the disadvantage of spending all but an infinitesimal fraction of its total existence in a condition unlike that which we observe," whereas the second model "has the advantage of spending all its life in a condition where there is a finite density of matter," which corresponds to all observations so far collected.[36] The strike against the first model, expressed here as its incompatibility with observation, suggests that (i) is a concern for Tolman. Further, there can be no doubt that Tolman dances around anthropic considerations which, as revealed in the Prologue, date back as far as Kant and only emerge in full force in the latter half of the twentieth century. In choosing to compare the two models, Tolman directly engages (ii)—and he does so, as mentioned, with the hint of anthropic reasoning that Earman voices in this section's opening passages. Tolman's support of the second model over the first indicates acceptance of (iii).

Many of the later-era contemporary accounts of multiverse argumentation are nowhere near as subtle as Tolman's account with respect to the inclusion of explanation. The first consideration needs to be Carter, whose writing on the anthropic principle is at the heart of most of the later explanation-centered argumentation. Carter writes:

> It is of course always possible—as a last resort, when no stronger physical argument is available—to promote a *prediction* based on the strong anthropic principle to the status of an *explanation* by thinking in terms of a 'world ensemble'. By this I mean an ensemble of universes characterized by all conceivable combinations of initial conditions and fundamental constants…Even though I would personally be happier with explanations of the values of the fundamental coupling constants etc. based on a deeper mathematical structure (in which they would no longer be fundamental but would be derived), I think it is worthwhile in the meanwhile to make a systematic exploration of the a priori limits that can be placed on these parameters (so long as they remain fundamental) by the strong anthropic principle. *If* it were to turn out that strict limits could always be obtained in this way, while attempts to derive them from more fundamental mathematical structures failed, this would be

[36] Tolman (1966), p. 401.

> able to be construed as evidence that the world ensemble philosophy should be taken seriously—even if one did not like it.[37]

Before taking note of the specific premises in the argument, let us first include passages from a couple of Carter's successors in the multiverse tradition. Consider Leslie, who writes:

> The presence of vastly many universes very different in their characters might be our best explanation for why at least one universe has a life-permitting character. Cosmologists now often suggest that our universe is fine tuned to Life's needs. Had it expanded just a trifle more slowly at early times, for example, then it would have recollapsed in a fraction of a second and how then could living beings have evolved?...Yet if there existed many billion universes with varying early expansion speeds then at least a few might be expected to expand at speeds just right for Life's purposes. It would be no surprise that the universe in which we living beings found ourselves was one of those few. An observational selection effect would be operating here, as pointed out by B. Carter and many others.[38]

And, likewise, Susskind advocates his string theory landscape—a two-tiered, dimensionally connected and spatially extended model—in part by writing the following:[39]

> To explain proposition X anthropically, we should first of all have reason to believe that not-X would be fatal to the existence of our kind of life. In the case of the cosmological constant, this is exactly what Weinberg found.
>
> Even if X seems wildly unlikely, a rich enough Landscape with enough valleys may make up for it. This is where the properties of String Theory are beginning to have an impact. At a few universities in the United States and Europe, the exploration of the Landscape has begun. As we will see, all signs point to an unimaginable diversity of valleys: perhaps more than 10^{500} of them.
>
> And last but certainly not least, the cosmology implied by the theory should naturally lead to a supermegaverse, so large that all the regions of the Landscape will be represented in at least one pocket universe. Once again, String Theory, when combined with the idea of Inflation, fits the bill.[40]

It takes little digging to recognize that (i), (ii), and (iii) are the operative elements in the passages from Carter, Leslie, and Susskind. All discuss fine-tuning and the need for its explanation, which exemplifies (i), and all explicitly reference reasoning according to the anthropic principle, inclusion of which is something Earman identified as a typical component of such arguments. The anthropic components are essential here, as Earman noted, because in conjunction with a

[37] Carter (1974), pp. 295-298. Emphasis and parenthetical phrases in original. Note that the material left out by the ellipsis seems to implement the *weak* anthropic principle rather than the strong. This suggests either that Carter himself did not yet have the distinction between the two firmly within grasp during this foundational work, or that the ensuing corpus of literature misunderstood Carter's intended labeling system for the principle.

[38] Leslie (1989), p. 70.

[39] See Chapter 5 for more details of Susskind's model.

[40] Susskind (2005), p. 187.

multiverse, they purportedly generate the best explanatory account. This translates into the general argument form as (ii). Finally, Carter's final sentence even essentially restates (iii) in different language—and the passages by Leslie and Susskind likewise allude to the conditional (iii).

6.4 Summary

We have seen here, through the course of a dozen explicit argumentative passages from theorists throughout the full spectrum of the multiverse tradition, a fairly clean partition of the arguments into three different types. These, labeled here the "pillars of multiverse argumentation," are arguments via implication of theory, arguments via induction, and arguments via explanation. Each is distinct from the others with respect to a crucial feature. The implication of theory pillar relies on the inner workings of the adopted theory of physics to provide a mechanism for generating the multiverse. The induction pillar relies on observations and empiricism to fuel the argument for the existence of other miniverses. The explanation pillar relies on the explanatory power of the multiverse to explain our universe. These crucial distinguishing features recur again and again, as is clear from the spread of argumentation drawn from all eras of multiverse thought.

The examples of argumentation provided in this chapter far from exhaust the available stock offered by the theorists from Chapters 2, 3, and 5. Nonetheless, undertaking a complete assimilation of all of the available instances of argumentation from the multiverse tradition would merely strengthen a case that has already received sufficient support in the preceding. As such, owing to limitations of space, creating an exhaustive compendium of individual instances of multiverse argumentation is a task for future endeavors; the important pieces necessary for the remainder of the present work are the three argument schema that have surfaced.

We turn next to the thread that unites the three pillars together. That thread turns out to be typicality assumptions. And it is that thread that ultimately reveals the fundamental problem of multiverse reasoning.

7
Typicality Assumptions

What began as merely a collection of cosmological models has become an organized tradition with a classification of model types and three well-defined argument schema put forth in defense of the various models. We here refine the analysis further.[1]

The next step involves identifying the common thread that runs through multiverse argumentation. This chapter is dedicated to identifying the common thread with typicality assumptions. The procedure for doing so will involve dissecting the three pillars of multiverse argumentation revealed in Chapter 6. Once it is verified that the inclusion of a typicality assumption is necessary to complete each of the three pillars of multiverse argumentation, the problematic implications of that result will be presented.[2]

Recall the three pillars, this time with monikers for quick reference throughout the chapter:

1. Implication of Physical Theory (henceforth (IMP)):

    (i) Assumed physics.
    (ii) If assumed physics, then the miniverse generation mechanism exists.
    (iii) If the miniverse generation mechanism exists, then more than one miniverse exists.
    (iv) If more than one miniverse exists, then the multiverse exists.
    C. The multiverse exists.

2. Induction (henceforth (IND)):

    (i) Actual or potential observation(s).
    (ii) A typicality assumption.
    (iii) If actual or potential observation(s) and typicality assumption, then other miniverses exist.
    (iv) If other miniverses exist, then the multiverse exists.
    C. The multiverse exists.

[1] Because we shift now to full philosophical analysis, the emphasis will skew toward contemporary models. These are the models under discussion in the literature, so drawing upon them (as opposed to models from earlier in the tradition) provides a nice segue for this material into the ongoing philosophical discussion of the multiverse hypothesis.

[2] The problematic implications will be the focus of Chapter 8.

3. Explanation (henceforth (EXP)):

   (i) A cosmological explanandum requires an explanans.
   (ii) *MULTIVERSE* provides the most appealing explanans.
   (iii) If *MULTIVERSE* provides the most appealing explanans, then the multiverse exists.
   C. The multiverse exists.

The ensuing argumentation is meant to show that the commonality of each of the pillars is the necessary implementation of a typicality assumption. Specifically, it will be shown that typicality assumptions are essential components buried within (ii) in each of the above pillars of argumentation.

The case of (IND) is straightforwardly simple: premise (ii) in that argument schema simply *is* a typicality assumption. No further attention, at this point, need be afforded to this case. The other two involve more complexity; each receives attention in a dedicated section in what follows.

7.1 Analyzing the (IMP) Pillar of Multiverse Argumentation

The breadth of the historical multiverse models presented in Chapters 2, 3, and 5 is convincing evidence that the instantiations of *MULTIVERSE* differ from each other according to the classification scheme put forth in Chapter 4. Those differences arise from the way in which the miniverses are generated. Let us now push this concept a bit more forcefully to see what it yields philosophically.

The satisfaction of *MULTIVERSE* (i)-(iii) is achieved, in uses of (IMP), by positing a miniverse generation mechanism. The miniverse generation mechanism is essential to the (IMP) pillar: premises (ii) and (iii) explicitly employ it. Premise (ii) ("If assumed physics, then the miniverse generation mechanism exists") is where attention will be directed.

Attention should be directed at (IMP) (ii) because (IMP) aims to establish *MULTIVERSE*, meaning the argument schema needs to establish each of *MULTIVERSE* (i)-(iii).[3] (IMP)

[3] Recognizing this helps to see one of the ways in which the (EXP) pillar is fundamentally different from the (IMP) pillar. The (EXP) pillar, through employing inference to the best explanation in its premise (ii), does not actually need to establish the separate claims ((i)-(iii)) of *MULTIVERSE* to argue for the multiverse's existence. Instead, the schema relies on *assuming MULTIVERSE* (i.e., assuming *MULTIVERSE* (i)-(iii)) and seeking to establish that under that assumption, we find the most plausible means of explaining the universe. (IMP), on the other hand, cannot merely assume *MULTIVERSE* (i)-(iii). Those claims need to be *established* through the argument schema for (IMP) to succeed.

accomplishes this by dedicating a premise to each of the three clauses of *MULTIVERSE*. (IMP) (i), which is the claim associated with the assumed physics of the theorist, includes information that leads to the satisfaction of *MULTIVERSE* (i), which is the claim that the spacetime structure is topologically connected.[4] (IMP) (iii), which claims "if the miniverse generation mechanism exists, then more than one miniverse exists," aims to establish *MULTIVERSE* (ii), which is the claim that the spacetime structure contains many causally disconnected regions.[5]

That leaves (IMP) (ii), which is the claim that the assumed physics imply the miniverse generation mechanism, to establish *MULTIVERSE* (iii).[6] Multiverse theorists are restricted from invoking an entity that is straightforwardly unjustified, lest they succumb to tagging it an initial condition. Doing so would remove a key advantage that the *MULTIVERSE* advocate wishes to secure against the *UNIVERSE* advocate: a physics that comes closer to deriving the phenomena of the universe from unified theory. Thus, some justification must lurk behind the claim that the physics establishes a miniverse generation mechanism. Furthermore, to implicate *MULTIVERSE* (iii) entirely, the justification must sufficiently establish that the miniverse generation mechanism produces miniverses that may exhibit different combinations of laws, parameters, and constants.

What is sought is an answer to whether one's assumed physics is capable of unilaterally implying a miniverse generation mechanism that creates miniverses that compositionally vary from each other. The claim argued for in this section is that something extra—a typicality assumption—is required in addition to the physics. A brief digression involving the constituents of mechanisms proves informative for investigating whether physical theory alone could provide the premises needed to establish the miniverse generation mechanism.[7]

The new mechanistic philosophy has chiefly—perhaps exclusively—focused on the biological sciences, though that need not deter us from attempting to import the results to the cosmological

---

[4] A properly adjusted version of *MULTIVERSE* (i) would be necessary for thorough assessment of (IMP) for models stemming from the ancient or modern eras, since topological connectedness is not a concern in those eras. The focus here is the contemporary setting.

[5] Certainly (IMP) (i) (i.e., the assumed physics) might likewise contribute to the establishment of the many causally disconnected regions, as well.

[6] (IMP) includes a fourth premise, which is the claim that the existence of more than one miniverse implies the existence of the multiverse. But (IMP) (iv) serves more as a deductive-completeness component for (IMP) as a whole than as a crucial piece necessary for establishing any of the parts of *MULTIVERSE*.

[7] Firmly establishing that the miniverse generation mechanism fully satisfies the definition of the term ("mechanism") in the current philosophy of science literature would require argumentation that would take us beyond the present scope of inquiry. Here, the link will be assumed for the purpose of gaining insight into what components would be necessary to construct a premise such as (IMP) (ii).

case at hand. The primary components of a mechanism include activities and entities, and mechanisms are the facilitators of change: "Mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions."[8] The "change" requirement is particularly pertinent when discussing the miniverse generation mechanism, since it was noted earlier that the crucial feature of *MULTIVERSE* that differentiates it from *UNIVERSE* is condition (iii).[9] *MULTIVERSE* (iii) is the condition that permits the changing of the physical constants from miniverse to miniverse. Therefore, if mechanisms are what facilitate change, the distinguishing feature between *UNIVERSE* and *MULTIVERSE* is the mechanism that produces the change from the one miniverse to the next. This makes intuitive sense. If a miniverse generation mechanism that changed the values of the physical constants (for example) were not in place, then each of the causally disconnected regions would exhibit the same values of the physical constants, leaving one without *MULTIVERSE* (iii) and, effectively, merely with *UNIVERSE*. Put another way: if the physical constants change, then something must be enacting that change. That is the function of the miniverse generation mechanism. So it seems that recent work on mechanisms (generally) would declare the aim of (IMP) (ii) to be worthy: mechanisms impart change, so the miniverse generation mechanism is what is needed to establish *MULTIVESE* (iii), which deals with the change between miniverses.

What is necessary for a set of physics to establish a miniverse generation mechanism in a legitimate way comes into focus. *MULTIVERSE* adherents are forced to account for it somehow when implementing the (IMP) pillar—and, as detailed in the various proposed multiverse models, there is no dearth of suggestions for it. But recall further that a miniverse generation mechanism requires justification to elevate it from the status of an initial condition; multiverse theorists need to be sure that their establishment of (IMP) (ii) is both necessary and justified if they are to outduel the *UNIVERSE* advocates. But unless the assumed physics itself includes explicit details about *exactly* how the miniverses end up different from each other, an extra assumption will be necessary (in tandem with the assumed physics) to satisfy the conditional (IMP) (ii). We turn now to the historical models to see whether any meet that requirement.

Recall the spatially scaled model from Chapter 5 that Smolin proposes. His Cosmological Natural Selection (CNS) is comprised of three hypotheses:

[8] Machamer, Darden, & Craver (2000), p. 3.
[9] See Chapter 1.

(a) A physical process produces a multiverse with long chains of descendants.

(b) For the space $\mathcal{P}$ of dimensionless parameters of the standard model of physics, there is a fitness function $F(p)$ on $\mathcal{P}$ which is equal to the average number of descendants of a universe with parameters p.

(c) The dimensionless parameters p_{new} of each universe differ, on average, by *small* random amounts from those of its immediate ancestor (i.e. small compared with the change that would be required to change $F(p)$ significantly).[10]

Quite clearly, this set of claims is intended, collectively, to establish something akin to (IMP) (ii). Smolin is attempting to utilize some assumed physics—in terms of the black hole production process—to establish the existence of a miniverse generation mechanism. CNS (a) refers to some physical account of gravitational collapse. CNS (b) likewise employs assumed physics—the standard model—to generate a "fitness function." But CNS (c) has a different flavor. It does not rely upon the physics Smolin assumes in CNS (a) and (b). Instead, it is an assumption—a typicality assumption. Smolin is claiming that miniverses that we cannot access are like the universe (in the particular ways he specifies).[11] Smolin implies a miniverse generation mechanism, for without it, he has no grounds for postulating a change in the values of the new miniverse, let alone for qualifying the change as "small" and "random." Smolin even refers to the way in which the values change as "the mechanism by which the parameters are selected," further cementing the fact that he intends to establish the content conveyed by (IMP) (ii).[12] But Smolin's version of (IMP) (ii) includes *more* than merely "assumed physics" in its antecedent, since it is not the *physics* that enacts the change in the parameters. CNS (c) is what does so. And CNS (c) is a typicality assumption.

There are additional historical models that exhibit the necessary addition of a typicality assumption to the antecedent of (IMP) (ii). Tolman writes, concerning the creation of miniverses within his temporally extended model, that "the mechanism of passage is not described by the present equations."[13] This is an explicit reference to the existence of a miniverse generation mechanism justified by means that include not only his assumed physics, but something beyond

[10] Smolin (2007), pp. 351-352. This is the same set of hypotheses that was cited in Chapter 5.

[11] See Carr (2007b), p. 84 for corroboration: "Smolin has argued that *most* of the universes should have properties like our own, so that ours is typical." Emphasis in original.

[12] Smolin (1997), p. 96.

[13] Tolman (1966), p. 401. This mention of Tolman is brief because his argumentation properly gets classed under the (EXP) pillar. He will, therefore, receive further mention in Section 7.2 below. Nonetheless, there can be no question about the intent in the cited bit of his work: he is attempting to establish a miniverse generation mechanism.

the physics. Tolman notes the mechanism, and further takes pains to mention explicitly that the assumed physics cannot account fully for that mechanism.

Perhaps no single bit of the multiverse corpus demonstrates the present point better than the following portion of the passage from Wheeler that was included in Chapter 5:

> Physics has long used the "black box" to symbolize situations where one wishes to concentrate on what goes in and what goes out, disregarding what takes place in between…Little as one knows the internal machinery of the black box, one sees no escape from this picture of what goes on: the universe transforms, or transmutes, or transits, or is *reprocessed* probabilistically from one cycle of history to another in the era of collapse.[14]

These passages provide strong evidence from the multiverse tradition that theorists seeking to employ (IMP) necessarily need more than just their assumed physics to establish the miniverse generation mechanism (and thereby to justify premise (ii) of (IMP)). The "more" is a typicality assumption that specifies what sort of miniverses the miniverse generation mechanism produces.

The point becomes clearer when considered as follows. What the miniverse generation mechanism provides is an account for the spawning of miniverses in accordance with *MULTIVERSE* (iii), specifically the possibility of differences between the miniverses. But the physics alone cannot be grounds for justifying a claim about the composition of other miniverses. The laws, parameters, and constants themselves—the essence of the assumed physics—*are themselves* the candidates for change from miniverse to miniverse in *MULTIVERSE* (iii). That, coupled with the causal disconnection included in *MULTIVERSE* (ii), assures that the physics gleaned from the universe cannot *alone* yield justification for the miniverse generation mechanism. Thus, with *only* the physics available, the miniverse generation mechanism would remain unjustified, leaving it with status no greater than an initial condition. However, what *can* speak to the composition of other miniverses is a typicality assumption. Indeed, that is precisely what a typicality assumption does. So, to prevent the (IMP) pillar from crumbling under the weight of the miniverse generation mechanism as merely an initial condition, a typicality assumption must be added to the antecedent of (IMP) (ii). When conjoined with the assumed physics, the typicality

[14] Misner, Thorne, & Wheeler (1973), pp.1209-1214. Emphasis in original.

assumption provides *some* sort of justification, little as it may be, for positing the miniverse generation mechanism. That prevents the miniverse generation mechanism from being relegated to nothing more than an initial condition.[15]

The above result brings to the fore the need for an adjustment to (IMP) (ii). Specifically, (IMP) (ii) needs to be reconfigured to:

> (IMP) (ii_{TA}) If assumed physics and a typicality assumption, then the miniverse generation mechanism exists.

The "TA" subscript indicates the presence of a typicality assumption. This adjustment would salvage the (IMP) pillar of argumentation; any instantiation of (IMP), now including (ii_{TA}) in place of (ii), avoids the charges that the miniverse generation mechanism is merely an initial condition contained within the physics.

So, then, the necessity of including a typicality assumption in the antecedent of (IMP) (ii) is the philosophical gain from the present analysis of the (IMP) pillar of multiverse argumentation. With it, the theorist employing (IMP) can defend against the objection that multiverse arises merely by fiat (essentially as an initial condition). Without it, the theorist cannot justify the establishment of the miniverse generation mechanism. Most important (for present purposes), however, is that (IMP) (ii_{TA}) includes a typicality assumption.

7.2 Analyzing the (EXP) Pillar of Multiverse Argumentation

Miniverses that collectively offer variation in their constituent parameters are essential to the effectiveness of the (EXP) pillar. Without them, as noted in Chapter 6, no explanation for the universe's properties can be gleaned from applying the Weak Anthropic Principle (WAP) to the set of miniverses. However, a deeper analysis reveals that this requirement belies the fact that (EXP) places a restriction upon *MULTIVERSE*. The restriction is the necessary inclusion of a typicality assumption.

To begin, an important subtlety must be addressed.[16] The cosmological explanandum represented in (EXP)(i) typically involves the fine-tuning of the universe's composition. But there

[15] The reader who notes that the problem of justification has merely been pushed up one level—to the level of the typicality assumption—has anticipated a piece of the assessment provided in Chapter 8.

[16] I wish to thank John Earman for bringing the ensuing distinction to my attention in personal conversation.

are two distinct senses in which the explanandum can "involve" the fine-tuning. The first would solicit an explanans for the actual composition of the universe. The second would solicit an explanans for *our observation of* the actual composition of the universe.[17] So, providing a full treatment of the (EXP) pillar requires addressing this distinction. The previous results of this study guide the way.

Those advocating an explanandum of the first type—an explanandum dealing with the actual composition of the universe—are treating of the multiverse hypothesis via the (IMP) pillar, not the (EXP) pillar. This much is clear from the preceding section, where we saw the assumed physics itself (plus, in the end, a typicality assumption) directly imply the miniverse generation mechanism. (IMP)(iii), which motivates the existence of multiple miniverses (and the universe) once the miniverse generation mechanism is in place, then provides the direct explanans for the universe's composition: the miniverse generation mechanism is responsible for the composition of *every* miniverse in the multiverse, and this *a fortiori* includes the universe. The process circumvents (EXP)(ii): there is no longer a "most appealing explanans." Instead, the physics itself (plus the typicality assumption) directly implies the composition of the universe. This is the argument structure of the (IMP) pillar. Accordingly, we may siphon off from the (EXP) pillar accounts such as the spatially extended inflationary models and the dimensionally connected string theory models; such models typically invoke the (IMP) pillar, not the (EXP) pillar, when addressing the universe's composition.[18] Rather than "explain" the composition of the universe via the multiverse hypothesis, they deduce it from theory—thereby implementing (IMP) rather than (EXP).

The same is not true in cases with explananda that deal with *our observation of* the universe's composition. That the WAP is deployed in virtually all such cases is strong evidence for the dichotomy, for the WAP is a principle that addresses our existence *as observers*.[19] The physics (plus a typicality assumption) could be used to deduce the composition of the universe (as detailed

[17] For a full treatment of this distinction, Craig (1988) is an excellent introductory resource.

[18] Unquestionably, this is a generalization that need not hold for *every* spatially extended inflationary model or *every* dimensionally connected string theory model. The deciding factor is whether the stakes involve (a) the composition of the universe, or (b) our observation of the composition of the universe. This determination needs to be made case-by-case. Further difficulty often arises due to the vacillation between the two within some accounts in the literature. See, for example, Weinberg (1989), where in some places he displays the difficulty of explaining the value of the cosmological constant (pp. 3-6, 9-20), but in some places shifts to "anthropic considerations" that might explain *our observation of* the value of the cosmological constant (pp. 6-9).

[19] See the Prologue and Chapter 6.

above), but those same items would not deduce *our observation of* the universe's properties in a similar fashion. The reason is simple: to claim otherwise would be to assent to the *necessary* emergence of observers, a proposition that multiverse theorists (and most other scientists) are reluctant to assent to.[20] Hence, among the possible accounts for *our observation of* the universe's properties, there really could be a "most appealing explanans," in accordance with (EXP)(ii). Those in the multiverse tradition propose that the most appealing explanans is *MULTIVERSE*.

Having tossed the other models over to the (IMP) pillar where they belong, we turn to the remaining accounts of (EXP) in the multiverse tradition, namely those targeting the multiverse as an explanans for *our observation of* the properties of the universe. The argumentation for these models rests on the premise that they provide the most appealing explanans for our observations of the universe's composition.

The models in question require a vast variety of miniverses from which an observational selection effect can winnow the options to just those akin to (and including) the universe. Thus enters the "mild and unobjectionable form of the Anthropic Principle," as forecast by Earman in the passage from Chapter 6. Turning to the tradition for examples of this sort, we find Leslie claiming:

> The cosmos may be one which oscillates, Wheeler fashion. Its force strengths etc. may change from cycle to cycle, randomly, making the cycles so different that each might count as 'a new universe'. Sooner or later, along comes a cycle in which the force strengths are just such as to permit observers to evolve. It is then unamazing that they should observe just those force strengths.[21]

And we find Weinberg writing:

> On the other hand, if ρ_V [the vacuum energy density] takes a broad range of values in the multiverse, then it is natural for scientists to find themselves in a subuniverse in which ρ_V takes a value suitable for the appearance of scientists. I pointed out in 1987 that this value for ρ_V cannot be too large and positive, because then galaxies and stars would not form. Roughly, this limit is that ρ_V should be less than the mass density of the universe at the time when galaxies first condense. Since this was in the past, when the mass density was larger than at present, the anthropic upper limit on the vacuum energy density is larger than the present mass density, but not many orders of magnitude greater.[22]

[20] This, of course, is the Strong Anthropic Principle (SAP), which will feature prominently in Chapter 8.
[21] Leslie (1988), p. 270.
[22] Weinberg (2007), pp. 31-33. Bracketed addition inserted for clarity.

And we saw, in passages in Chapter 6, Hume referring to "uniformity of appearance" and Tolman rejecting a model owing to its "disadvantage of spending all bit an infinitesimal fraction of its total existence in a condition unlike that which we observe."[23] Both of those models, recall, were temporally extended models with miniverses that differ extensively from each other.

In all of the examples above, the respective multiverse models are intended to provide the explanans for our observation of the universe's fine-tuned composition.[24] Essential to that aim is the variety of the tier of miniverses on which the WAP operates. Without the variety, there is no "selection" from the observational selection effect. The lack of selection would cause the multiverse model to fail to satisfy (EXP)(ii): it would no longer provide the most appealing explanans. For example, the scientifically desired virtue of simplicity would cause the model to be defeated easily by the cosmological account that posits just our single universe. The variety removes this obstacle and establishes the grounds for arguing that the multiverse provides the most appealing explanans.

But the requirement of variety has repercussions for the theorist seeking to implement the (EXP) pillar. In particular, the necessity of variety among the miniverses places a subtle restriction on *MULTIVERSE*, which can be pinpointed as follows. It is a very simple, slight adjustment. Within *MULTIVERSE*, (iii) reads:

> (iii) The causally disconnected regions may exhibit different combinations of laws, parameters, and constants.

However, via the argumentation presented in this section, theorists employing the (EXP) schema implicitly drop the "may" from (iii). This leaves an adjusted version of (iii) that reads:

> (iii)$_{TA}$ The causally disconnected regions exhibit different combinations of laws, parameters, and constants.

As in the previous section, the subscript is meant to indicate that the statement is a typicality assumption; in this case, it is very clear that (iii)$_{TA}$ is the Atypicality assumption. It is the claim that what lies outside the universe is different from what lies within the universe.

The (EXP) pillar of multiverse argumentation has, as a crucial premise, its claim (ii), which is that *MULTIVERSE* provides the most appealing explanans (for the explanandum comprised of our observation of the orderliness of our universe). What has been demonstrated here is that (ii) is

[23] See Chapter 6 for the full passages and citations.
[24] That the multiverse provides *the most appealing* explanans, as (EXP) (ii) dictates, must be provided by each theorist within his or her specific model, as detailed in Chapter 6.

established only by means of implicitly taking the Atypicality assumption in the formulation of *MULTIVERSE*. This Atypicality assumption wiggles in undetected. In the end, then, with respect to explaining our observations of the universe, typicality assumptions dictate the result: the (EXP) pillar of multiverse argumentation, in its premise (ii), balances completely upon a typicality assumption.

8
The Problematic Implications of Typicality Assumptions

Typicality assumptions infest multiverse argumentation. That much was gleaned from Chapter 7. What follows is the exposition of the problems created by the multiverse tradition's necessary reliance on typicality assumptions.[1] Each of the pillars of multiverse argumentation suffers a particular plight, and a universal plight plagues them all.

The (IMP) pillar's reliance upon typicality assumptions amounts to nothing more than the addition of a hidden initial condition. The (IND) pillar's reliance upon typicality assumptions amounts to making an inductive inference from a sample of size one. The (EXP) pillar's reliance upon typicality assumptions brings with it a veiled version of the detested Strong Anthropic Principle, thereby generating an internal inconsistency within the schema's second premise.

Perhaps most detrimentally, the typicality assumptions that underwrite all three pillars necessarily lack justification. Here, Hume's demonstration returns—in analogous form—against the use of typicality assumptions in multiverse cosmology. Whereas Hume's traditional problem of induction rejects justification across *times* (from the present to the future), the Multiverse Circularity Problem (MCP) rejects justification across *places* (from the universe to other miniverses).

8.1 Particular Problem: (IMP) and Typicality Assumptions

Those wielding (IMP) do so under the guise that the multiverse can obviate some initial conditions within physical theory, which would be a virtuous mark in favor of multiverse models. The cost of doing so is the inclusion of typicality assumptions. Those typicality assumptions merely take the spot of the circumvented initial conditions, leaving the multiverse theorist without the claimed

[1] Recall that "typicality assumption" (lowercase 't') refers to the disjunction "Typicality assumption or Atypicality assumption." It is the "generic" reference to either assumption. The capitalized versions—Typicality assumption and Atypicality assumption—are the specific claims of similarity and dissimilarity (respectively) between the universe and other miniverses within a tier of the multiverse.

advantage. The necessary shift from (IMP)(ii) to (IMP)(ii_{TA}) removes the miniverse generation mechanism from "initial condition" status, but it places that same status squarely upon the typicality assumption.[2]

To demonstrate precisely how typicality assumptions hijack the intended result, let us return to Smolin's spatially scaled model.[3] CNS(a) is enacted, in the form of a web of black hole descendants, upon which CNS(b) steers the web in the direction of descendants that exhibit more "fitness" with respect to the propensity to produce black holes. The mechanism whereby the web's nodes differ from each other is given by CNS(c).

Smolin's model introduces the Typicality assumption twice. The first occurrence was identified in Chapter 7: the model needs (CNS)(c) to specify precisely the familial resemblance between the "baby" miniverses and the "parent" miniverses, lest the offspring miniverses develop merely as one-shot burnouts that leave no progeny. (CNS)(c) is the Typicality assumption; it likens other miniverses to the universe. The second occurrence of the Typicality assumption is the model's intrinsic requirement that the first miniverse must be a black-hole-producing miniverse, lest the original miniverse be barren and produce no children. This, too, likens our universe to what lies outside it (namely, the "original" miniverse). The removal of either Typicality assumption stagnates the operation of the miniverse generation mechanism, which in turn eliminates the multiverse because *MULTIVERSE* (iii) fails to obtain.[4]

Having identified both of the relevant assumptions as instantiations of the Typicality assumption, it is a trivial task to show that they further are identical with initial conditions. Clearly, they are: the requirement that the initial miniverse be black-hole-producing is nothing but an initial condition of the physics Smolin proposes. Likewise for (CNS)(c): without initially tuning the dial of (CNS)(c) to differences of "*small* random amounts" rather than cranking the dial to, say, "*large* increasing amounts," Smolin's model fails to get off the ground. With respect to the properties of the initial universe, Smolin himself recognizes that his assumption is merely an assumed restriction on the initial conditions of his model:

---

[2] See Chapter 7. (IMP)(ii) claims "If assumed physics, then the miniverse generation mechanism exists." (IMP)(ii_{TA}) adds a typicality assumption to the antecedent: "If assumed physics and a typicality assumption, then the miniverse generation mechanism exists."

[3] See Chapter 7 for a summary of Smolin's model.

[4] This is further (supplementary) argumentative support for the result of Section 7.1, which argued for the necessity of the shift from (IMP)(ii) to (IMP)(ii_{TA}) for an instantiation of the (IMP) pillar to argue validly for the existence of the multiverse.

> An empty universe has no progeny. If we create a universe without progeny the process simply stops. For the sake of argument, we must restrict the allowed parameters of this initial universe, and all those created from it, so that each one has at least one descendent. This is easy to do; it means we must require that each universe contain enough matter for the gravitational attraction to reverse the expansion, leading to its total collapse and, hence, at least one bounce.[5]

The italicized portions of the passage have been emphasized to draw attention to their status as initial conditions of the model. Smolin's implementation of the Typicality assumption merely functions as camouflage for the initial conditions necessary for the physics that govern his model.

Smolin's model nicely exemplifies the particular problem that haunts the (IMP) pillar. The shift from (IMP)(ii) to (IMP)(ii_{TA}) is necessary in order to justify the use of the miniverse generation mechanism. The miniverse generation mechanism is necessary for the satisfaction of *MULTIVERSE* (iii).[6] Without *MULTIVERSE* (iii), the multiverse theorist possesses a model that does not differ appreciably from *UNIVERSE*.[7] Thus, any justification for supporting *MULTIVERSE* rather than *UNIVERSE* via the (IMP) pillar can be traced to the inclusion of a typicality assumption, but the necessary inclusion of a typicality assumption cannot be divorced from its status as an initial condition of the theory. Theorists who employ (IMP) gain their advantage over *UNIVERSE* theorists precisely from the ability to derive the universe from reliance upon fewer initial conditions. But alas, that advantage is a mirage. The necessary typicality assumptions are nothing more than packaging that contains initial conditions of the assumed physics.

Lest the charge be leveled that this weakness is particular to Smolin's spatially scaled multiverse model, we can draw upon the multiverse tradition for further support. For example, nearly all temporally extended models, including Wheeler's, take the Typicality assumption with respect to the expansion rate of the miniverses. Earman puts it succinctly: "if the expansion rate of a "cycle" is sufficiently great, recollapse will not take place and the scenario will destroy itself."[8] In order to maintain the model, the miniverses are assumed to have a likeness with our universe pertaining to the expansion rate. This is an initial condition built into the model that enters with the necessary Typicality assumption.

---

[5] Smolin (1997), pp. 96-97. Emphasis added.
[6] See Chapter 1 for the full definition of *MULTIVERSE*. *MULTIVERSE* (iii) dictates that the miniverses may exhibit different combinations of laws, parameters, and constants.
[7] See Chapter 1.
[8] Earman (1987), p. 311.

8.2 Particular Problem: (IND) and Typicality Assumptions

The inductive problem associated with extrapolating from our finite collection of cosmological observations to the infinite unobserved remainder is widely recognized. The necessary inclusion of a typicality assumption in the (IND) pillar creates a stronger multiverse correlate to this traditionally *UNIVERSE*-based problem: the typicality assumption operates as a rule of inference from a sample of size one (the universe) to an infinite population of miniverses. We now unfold the associated details, first by likening the multiverse case to the familiar problem from traditional cosmology and then by showing how the shift to multiverse cosmology exacerbates the problem.[9]

The correlation between the problematic nature of inductive inference for *UNIVERSE* cosmology and that for *MULTIVERSE* cosmology becomes evident through study of the *UNIVERSE*-based Cosmological Principle (CP).[10] CP asserts that "the universe is spatially homogeneous and isotropic at large scales."[11] Of import here are both the content of CP and the difficulty involved in its justification.

With respect to content, CP specifies a way in which uninvestigated pieces of our universe are similar to the investigated pieces. This clearly identifies it as an instantiation of the Typicality assumption. It is here that the connection to *MULTIVERSE* becomes apparent, for (IND) likewise employs a typicality assumption in its premise (ii). (IND)(ii) usually is instantiated by the claim that other miniverses are similar to the universe.[12]

Many accounts report the difficulties involved in obtaining a foundational justification for CP.[13] I will not repeat them here. Instead, I merely convey the difficulty—in the form of the brief synopsis below—in preparation for argumentation that the suitable extension of the problem into the domain of multiverse cosmology in fact *amplifies* the problem.[14]

---

[9] While the problem detailed in this section might be *less surprising* than the problems outlined for the other two pillars of multiverse argumentation, this should not be taken as an indication that the problem is *less serious* than the problems presented for the other two pillars. Indeed, the problem for the (IND) pillar very well might have the strongest roots, if only because the problem already has withstood the test of solution-seekers in cosmology for quite some time. Additionally, an extension of the problem outlined in this section will be pivotal for establishing the Multiverse Circularity Problem, which is presented in Section 8.4.

[10] See Chapter 1 for definitions of *UNIVERSE* and *MULTIVERSE*.

[11] Beisbart (2009), p. 176.

[12] See Chapter 6 for further details and examples.

[13] See, for example, Beisbart (2009) and Beisbart & Jung (2006).

[14] The difficulty of justifying CP will receive additional attention in Section 8.4. Further, Chapter 9 involves exposing the necessary adjustments required for shifting from principles (like CP) that govern *UNIVERSE*-based

The justification sought would permit the extension of knowledge from a small part of our universe to the whole. Butterfield gives an example of the difficulty involved in obtaining it:

> [C]onsider matter or radiation that left our past light cone at about the time of decoupling—as it might be, a cosmic background photon. That photon is estimated to now be about 40 billion light-years from us (the distance being measured along the cosmic time-slice t = now). Vast indeed. This vastness emphasizes how risky is the induction from CP's holding in the observable universe…to its holding throughout any such region…To put the point very simply, in terms of enumerative induction over spacetime regions: the observable universe is such a small fraction of such regions, that it is risky to claim it is a fair sample.[15]

Attempts to justify the use of typicality assumptions in the (IND) pillar face an increased amount of the riskiness of which Butterfield speaks. Under *UNIVERSE*, inference takes place (with the help of CP) from the ever-increasing observed regions to the unobserved regions of the universe. The number (or volume) of observed spacetime regions increases as observations are collected, but even still, as Butterfield notes in the quoted passage, there remains considerable risk when inferring from that small sample to the rest of the universe.

In the multiverse case, the (IND) pillar (with the help of a typicality assumption) seeks to apply an inductive inference from the universe to other miniverses. Yet the gathering of observations within our universe, while still perhaps offering fodder for inductive inference *within* it via CP, does nothing with respect to offering confirmation for the properties *outside* of it. Thus, our increasing success within our universe provides no help in justifying the cosmological induction—the use of the typicality assumption—in (IND)(ii). Any gathered information applies merely to our universe. The shift to the multiverse scenario *reduces* the size of the sample to the smallest possible size (one), while at best leaving the population size unchanged (infinite).[16] The difficulties inherent in justifying CP for *UNIVERSE* theorists are thereby compounded for *MULTIVERSE* theorists trying to justify the use of the typicality assumption in (IND)(ii).

Thus we see the particular problem introduced by typicality assumptions to (IND)-driven multiverse cosmology. The problem can be expressed as the simplest possible form of illicit induction: the typicality assumption in (IND), quite literally, involves an inductive inference to the population from a sample of size one.

---

cosmology to principles that govern multiverse cosmology. These facts make this exposition of (IND) and its problem particularly fruitful as a point of departure for future research.

[15] Butterfield (2014), p. 63.

[16] Certainly there are model-by-model considerations that need to be differentiated from each other. But, as the results of Chapters 2, 3, and 5 show, the majority of multiverse models involve an infinite number of miniverses.

But the situation is worse still. Further exacerbating the difficulty is the stipulation that we *necessarily* have access to exactly one miniverse. Multiverse cosmologists themselves lay down this tenet, and it is captured by condition (ii) of *MULTIVERSE*.[17] This is the crucial difference that guarantees amplification of the already-difficult justificatory problem. Whereas *UNIVERSE* advocates inherit no restrictions on the possibility of acquiring further evidence with which to strengthen their inductive inference—even if that strengthening is meager—*MULTIVERSE* advocates wielding (IND) are perpetually trapped in a situation wherein no acquired evidence can strengthen their inductive inference at all.

8.3 Particular Problem: (EXP) and Typicality Assumptions

Chapter 6 established that most contemporary arguments for the multiverse via explanation incorporate some element of anthropic reasoning—specifically some version of the weak anthropic principle (WAP)—in order to establish premise (ii) of the (EXP) argument schema.[18] This is acceptable within the discipline because, as is widely recognized, the WAP is taken to be an innocuous principle (due to its tautological nature). The same tolerance is not afforded to the strong anthropic principle (SAP), which is cast off as unscientific because it requires, without justification, the emergence of observers. Here, we demonstrate how the necessary reliance on the Atypicality assumption smuggles that same much-maligned content into (EXP)(ii). This creates an internal inconsistency: proponents of (EXP) denounce SAP while simultaneously employing the very same denounced content through the use of (EXP)(ii).

The (EXP) argument schema requires the inclusion of the Atypicality assumption to succeed.[19] The systematic process implemented in the Prologue for dissecting the WAP into its constituent parts will be revisited here to dissect the SAP.

The SAP, in its original form, claims that "the Universe (and hence the fundamental parameters on which it depends) must be such as to admit the creation of observers within it at some stage."[20]

---

[17] See Chapter 1. *MULTIVERSE* (ii) claims that "The spacetime structure contains many causally disconnected regions." These are the separate miniverses that comprise the multiverse.

[18] Recall, for example, Earman's statement to this effect, as well as the passages from Carter, Leslie, and Susskind that directly confirm Earman's claim.

[19] See Chapter 7. The Atypicality assumption is involved due to the necessity of dropping the "may" from clause (iii) of *MULTIVERSE*, generating $(\text{iii})_{\text{TA}}$ (which is the Atypicality assumption).

[20] Carter (1974), p. 294.

It is wholly rejected as an admissible scientific premise because it introduces a restriction on the universe without proper justification for doing so. This is easily demonstrated by breaking Carter's statement into its simple components to isolate them, as follows:

> SAP_1: The universe is defined by its laws, parameters, and constants.
>
> SAP_2: The laws, parameters, and constants necessarily result in the emergence of observers.

Collectively, SAP_1 and SAP_2 are equivalent to SAP. SAP_2 is responsible for the rejection of SAP from legitimate scientific explanations for the emergence of our observations. The task now involves establishing a direct link between SAP_2 and (EXP)(ii).

SAP_2 links SAP to theories of benevolent creation or intelligent design. Advocates of those theories claim that the fine-tuned nature of the laws, constants, and parameters of the universe (as evidenced by the existence of observers) is seemingly too outlandish to have occurred merely by chance. This is the conventional interpretation of SAP that earned it a poor—perhaps nonexistent—scientific reputation. The multiverse, instead, has been recognized in the literature as the disjunctive alternative to a benevolent creator with respect to explaining our observations of the universe.[21] So, for example, Gribbin and Rees write:

> But the question remains—*is* the Universe tailor-made for man? Or is it, to extend that analogy, more a case that there is a whole variety of universes to "choose" from, and that by our existence we have selected, off the peg as it were, the one that happens to fit?[22]

And likewise, Craig writes, "We appear then to be confronted with two alternatives: posit either a cosmic Designer or an exhaustively random, infinite number of other worlds."[23] So *MULTIVERSE* is taken to be the scientific competitor of non-scientific benevolent creation theories—which are in turn instantiations of *UNIVERSE*—when it comes to explaining our collected observations.

But something very important has been done by these scholars. They have embraced the Atypicality assumption, directly in line with *MULTIVERSE* $(iii)_{TA}$, as required per the results of Chapter 7. This move appears to explain our collected observations of the universe without being

[21] This is so, even though the multiverse is rarely presented as having any relation at all to the SAP apart from Carter's brief musings at the end of his 1974 piece. I suspect that this is a case of good "scientific marketing" in the sense that distance from SAP is viewed favorably in the sciences. However, I also suspect that the marketing campaign was originally so successful that most current multiverse adherents do not recognize the connection to SAP; this is part of the main thrust that I'm seeking to establish at present.

[22] Gribbin & Rees (1990), p. 269.

[23] Craig (1988), p. 395. See Mosterín (2004) for more examples linking the multiverse and theories of a benevolent creator as competing hypotheses.

forced to the scientifically unsavory consequences of benevolent creation theories. Since the laws, parameters, and constants exhibit different combinations from miniverse to miniverse, the multiverse substantially widens the possibility for the emergence of observers in *some* region.

But the question has been begged. Employed in his fashion, the Atypicality assumption smuggles in the content of SAP_2: the multiverse is taken to exhibit the entirety of the possibility space created by the combinations of the values of the laws, parameters, and constants. The full set of miniverses can be pared to a subset that includes only those observer-friendly miniverses, *the existence of which are guaranteed* if one assumes that the miniverses in the multiverse are exhaustive.

The exhaustive multiverse captures the only miniverse that is important for (EXP) advocates: our universe. So long as that miniverse is included, the sought explanandum is secured. The Atypicality assumption is the tool used to secure the exhaustive multiverse. The Atypicality assumption's assertion that other miniverses differ from the universe is expanded to the exhaustive case in the literature: Susskind writes, "Even if X seems wildly unlikely, a rich enough Landscape with enough valleys may make up for it… *all the regions of the Landscape will be represented in at least one pocket universe*."[24] Carter envisioned "an ensemble of universes characterized by *all conceivable combinations* of initial conditions and fundamental constants."[25] And Craig presents the position of the (EXP) defender as requiring precisely an exhaustive set of miniverses.[26] The Atypicality assumption's inclusion makes our observations of the universe necessary in the very way that SAP_2 does: it merely presupposes them from the outset.

(EXP)(ii) claims that "*MULTIVERSE* provides the most appealing explanans" for our observations of the universe's properties. We see now that it only provides the most appealing explanans—better than the *UNIVERSE* offerings—if the Atypicality assumption is included. But the Atypicality assumption brings with it the content of SAP_2. Thus, quite illicitly, the multiverse provides the "better" explanans because it requires the existence of miniverses in the multiverse that generate our observations *simply by assumption*. (EXP) commits the very transgression for

[24] Susskind (2005), p. 187. Italics added for emphasis.
[25] Carter (1974), p. 295. Italics added for emphasis.
[26] See Craig (1988), especially pp. 394-395, for his articulation that the Atypicality assumption brings with it an exhaustive set of miniverses.

which multiverse theorists reject SAP in the first place; the move is illegitimate by the very standards of multiverse theorists. The culprit is the Atypicality assumption required for justifying (EXP)(ii).

8.4 Universal Problem: The Multiverse Circularity Problem

The material from Chapters 6 and 7 has shown that *MULTIVERSE* is justified only through invoking typicality assumptions: all argumentation for proposed models falls under one of the three pillars of argumentation, and those three pillars each require the use of a typicality assumption to succeed. One may expect, then, that independent justification for the use of typicality assumptions is forthcoming from the tradition, especially because all of the foregoing particular problems from Sections 8.1-8.3 could be wiped away with such justification. It would permit those using (IMP) to reclaim their advantage with respect to deriving the universe from fewer initial conditions, since the typicality assumptions would be initial conditions no longer (based on their derivation from the emergent justification). It would permit those using (IND) to justify their induction by way of the emergent justification for the employed typicality assumption. And it would permit those using (EXP) to reaffirm the claim that the multiverse provides the most appealing explanans for our observations, since the emergent justification would provide the needed distance from the unscientific content of the SAP. Alas, such justification is not offered by the tradition. In what follows, I argue that the situation is worse: it is not evident how such justification can be forthcoming. The most likely candidate to perform the task is enumerative induction, but as will be detailed shortly, that route leads to a familiar philosophical failure. At present, the only justification available for the use of typicality assumptions appears to be their mere assertion within *MULTIVERSE* itself.

Thus, a universal problem emerges with the use of typicality assumptions in the multiverse tradition. I label it the Multiverse Circularity Problem (MCP), and it is this:

> MCP: *MULTIVERSE* is justified only through invoking typicality assumptions, but typicality assumptions are justified only through invoking *MULTIVERSE*.[27]

[27] An even stronger version of MCP in fact may obtain. That version reads, "*MULTIVERSE can be* justified only through invoking typicality assumptions, but typicality assumptions *can be* justified only through invoking *MULTIVERSE*." It is stronger because it involves all *possible* multiverse models, whereas the version I present here

The first conjunct of MCP was established in Chapter 7. In this section, argumentation for the second conjunct will be presented. The simplest means of establishing the conjunct was revealed throughout the earlier portions of the project: theorists in the multiverse tradition hitherto have proceeded largely without revealing any concern that typicality assumptions have infiltrated their argumentation. So no detailed justification for their use of typicality assumptions has surfaced. Thus, in a strictly documented sense, it is true that typicality assumptions are justified only through invoking *MULTIVERSE*.

But the problem has a firmer foundation than the mere fact that there is not yet a literature of failed attempts to reference. A brief sketch of the parameters of the problem provides a glimpse of what the literature will be facing. What is needed is a justification for typicality assumptions that is grounded outside of the multiverse hypothesis. There are several candidates for accomplishing this task, among them the Bayesian approach and enumerative induction. But the Bayesian approach, for example, faces the prospect of formulating a prior probability distribution for a tier of miniverses to establish the veracity of the typicality assumption in question; such tinkering will build in the desired result from the start (or face charges of doing so).[28]

I wish to give the case of enumerative induction a fuller treatment. I do so because multiverse theorists are likely to turn here first. Specifically, cosmologists implement enumerative induction via the Cosmological Principle. As noted in Section 8.2, the Cosmological Principle (CP) is the assertion that "the universe is spatially homogeneous and isotropic at large scales."[29] That it is the inductive principle of choice for cosmologists is evident from the following series of passages. The first two come, respectively, from Bernard Schutz (physicist) in 2003 and from Joshua Knobe (philosopher of science), Ken Olum (cosmologist), and Alexander Vilenkin (cosmologist) in 2006:

> The Copernican principle is *basically a philosophical assumption*, but this does not make it unscientific…The Copernican principle must be tested, of course: we cannot accept any guiding principle if it predicts things that conflict with observations. Everywhere we look in the Universe, we observe that its appearance in any one region is very similar to that in another with the same cosmological age…In each case, the properties are the same everywhere they can be measured. This fact has a name: the Universe is homogeneous.[30]

---

involves *extant* models. With millennia of evidence for the presented version, it is quite possible that the stronger version has it right, though further argumentation would be required to establish it.

[28] See Chapter 9 for references involving attempts to apply probability distributions to tiers of miniverses.

[29] Beisbart (2009), p. 176.

[30] Schutz (2003), pp. 347-348. Italics removed from the word "homogeneous" to avoid confusion regarding the remaining italicized portion, which has been added for emphasis. Do not let the shift to the Copernican Principle

> [E]ven if we are never able to make observations concerning events outside the presently observable region, our knowledge of the presently observable region *may permit us to make justifiable inferences* concerning events in other parts of the universe.[31]

The fact that Schutz (in the first passage) deals with the Copernican Principle—a relative of the Cosmological Principle—via enumerative induction provides evidence that cosmologists generally resort to that very tactic when pressed to provide justification for their cosmological induction. It is the standard justificatory strategy for induction in many alternative cosmological frameworks, including multiverse cosmology. Olum and Vilenkin are multiverse cosmologists, and they explicitly employ enumerative induction in the second passage.

A second set of passages displays the standard attempts—and struggles—to justify cosmological induction. The passages come, respectively, from Hermann Bondi (co-discoverer of steady state cosmology), Steven Weinberg (particle physicist and Nobel laureate), and Frank Wilczek (theoretical physicist and Nobel laureate):

> [W]e may consider the simplicity postulate as a basis for the cosmological principle. This is the point of view adopted by the proponents of general relativity and is effectively that in our present ignorance of the universe *progress may most easily be made by assuming, purely as a working hypothesis*, that the large-scale structure of the universe is as simple as possible and hence it is uniform.[32]

> There remains the possibility that the universe is not homogeneous and isotropic after all. It might be homogeneous but not isotropic, as in the model of K. Gödel. However, the cosmic microwave radiation…appears to be highly isotropic…The real reason, though, for our adherence to the Cosmological Principle *is not that it is surely correct, but rather, that it allows us to make use of the extremely limited data* provided to cosmology by observational astronomy.[33]

> The most profound result of observational cosmology has been to establish the Cosmological Principle: that the same laws apply to all parts of the observed Universe, and moreover matter is—on average—uniformly distributed throughout. *It seems only reasonable*, then, to think that the observed laws are indeed universal, *allowing no meaningful alternative*, and to seek a unique explanation for each and every aspect of them.[34]

The passage from Butterfield provided in Section 8.2 could likewise be included here; it expresses the same hesitancy expressed in these three passages. These passages span almost five decades,

---

(from the Cosmological Principle) detract from the relevant point: in either case, the reasoning offered by cosmologists for establishing homogeneity involves the same process of enumerative induction.

[31] Knobe, Olum, & Vilenkin (2006), p. 55. Italics added for emphasis.

[32] Bondi (1968), p. 13. Italics added for emphasis.

[33] Weinberg (1972), p. 408. Italics added for emphasis.

[34] Wilczek (2007), p. 46. Italics added for emphasis.

and their authors are some of the most prominent to appear in the cosmology literature. Nevertheless, as indicated by the italicized portions of the passages, they are unable to provide a strong foundational justification for CP. We see in these passages the discomfort of their authors. They are aware of the difficulty of justifying CP. Yet, they are unable to find any "meaningful alternative" to it. They call it a "working hypothesis." Having experienced inductive success thus far, they leap to CP itself. One cannot be certain of the specific justification that any particular theorist might produce. Nonetheless, the suggestion (gathered collectively from the provided passages) is that enumerative induction completes the task because, as might be said colloquially, CP has "worked so far."

CP has held for already-gathered observations. It has never failed. So we should expect its continued success. Cosmologists and philosophers of science offer precisely this rationale: the two sets of passages show, in both temporal and theoretical contexts, that cosmologists turn first to enumerative induction.

However, relying on enumerative induction as the justification for further inductive inferences leads directly to a familiar philosophical foe. In brief, attempts to justify cosmological induction through enumerative induction summon a variant of Hume's notorious inductive problem. In its traditional form, Hume's problem provides a clear depiction of the difficulty associated with justifying enumerative induction. That difficulty also arises when we try to justify the Cosmological Principle. To see this, and further to display the severity of the problem for multiverse cosmologists, we turn to Hume's argumentative template. The demonstration relating the two cases is quick and decisive.

Hume's original language describes the problem of induction as an inherently *temporal* problem. The key to applying Hume's argument in the cosmological setting is to translate it into a *spatial* version. The original passage from Hume and a brief reconstruction of the argument's form are indispensable for the ensuing analysis. Hume's original passage reads:

> [A]ll our experimental conclusions proceed upon the supposition, that the future will be conformable to the past. To endeavor, therefore, the proof of this last supposition by probable arguments, or arguments regarding existence, must be evidently going in a circle, and taking that for granted, which is the very point in question…To say it is experimental, is begging the question. For all inferences from experience suppose, as their foundation, that the future will resemble the past, and that similar powers will be conjoined with similar sensible qualities…It is impossible, therefore, that any arguments from experience can prove this resemblance of the past to the future; since all these arguments are founded on the

> supposition of that resemblance. Let the course of things be allowed hitherto ever so regular; that alone, without some new argument or inference, proves not, that, for the future, it will continue so. In vain do you pretend to have learned the nature of bodies from your past experience.[35]

Articulating Hume's argumentation in the cosmological setting begins with identifying the original argumentative structure.

Any enumerative induction, in reaching a conclusion about some future experience, follows a standard schematic. That schematic can be represented as follows:

(1) Every past experience *A* has been *B*.

——————(T)

(C) The next experience *A* will be *B*.

Note that the premise (1) is a compressed, exhaustive conjunction of (presumably) many individual experiences, all of which exhibit experience *A* being *B*, without any *A* that are not *B*. Listing those experiences as separate premises would more clearly mark the induction to the next experience as *enumerative*.

As Hume's passage indicates in several places, the key feature of the argument is that any justification for enumerative induction from experience includes a rule of inference such as "the future will be conformable to the past." Hume then argues that this rule cannot be justified except circularly. The lettered line of separation in the schematic represents that rule of inference. It is labeled T to suggest that the inference rule operates across *times*:

T: What has been so will continue to be so.

Justification for the inference thus depends upon the justification for rule T. Such justification, notes Hume, only can be of the following sort:

(1) Rule T succeeds for the past.

——————(T)

(C) Rule T succeeds for the future.

Hume thus argues that all justification for T rests upon a circularity. The result is a failure of all attempts to justify the inference overall. Breaking the circularity requires access to the future, which is necessarily an inaccessible time.

Cosmologists face the same justificatory impasse, save for one small adjustment: the cosmological inferences to be justified through enumerative induction span *place* rather than

[35] Hume (1999), pp. 115-117.

time.[36] This simple difference is not trivial. Hitherto, the philosophy of science literature has not recognized the difference explicitly. The lacuna leaves incompletely grounded any claim that Hume's problem is ubiquitous in scientific endeavors, since some scientific endeavors (such as cosmology) involve induction in the spatial dimension rather than in the temporal dimension. By filling the lacuna, the argumentative force of Hume's conclusion is restored in at least one branch of science (cosmology). Perhaps the argumentation presented here will apply to other branches of science, but that task is deferred to future research.

Cosmologists seek justification for the inference to a claim such as "Unobserved place *A* is *B*." Using Hume's original schematic as a template, the cosmological variant now emerges clearly, beginning with the cosmological inference itself:

(1) Every observed place *A* is *B*.

——————(P)

(C) Unobserved place *A* is *B*.

As before, we make the rule of inference explicit. The rule needs to link observed places to unobserved places. The result is rule P:

P: What is here so is there so.

P (so labeled to suggest that the inference rule operates across *places*) is the correlate of rule T in Hume's original argument. Importantly, just as the class "has been so" (from rule T) continually grows as time proceeds, so too the class "is here so" (from Rule P) continually grows as observations are gathered.

Justification for the inference now depends upon the justification for rule P. But, just as in Hume's version, such justification only can be circular:

(1) Rule P succeeds for here.

——————(P)

(C) Rule P succeeds for there.

The only means of justifying rule P is via rule P itself. As in Hume's original formulation with respect to the future, breaking the circularity depends upon the ability to access the other places ("there"). But "there" is inaccessible from "here," just as the future is inaccessible from the present.

---

[36] I use "place" rather than something more multiverse-specific (such as "miniverse") so that the demonstration remains applicable to cosmological induction generally. As suggested in Section 8.2, the problem proves even more intractable in the multiverse setting. Extended details of that scenario will follow the present analysis.

To see Hume's problem reborn cosmologically, the relationship can be displayed clearly as follows, with correlations distinguished:

	Hume (across times)	Cosmology (across places)
Inference	Every **past experience** *A* **has been** *B*. ——————(**T**) The **next experience** *A* **will be** *B*.	Every **observed place** *A* **is** *B*. ——————(**P**) **Unobserved place** *A* **is** *B*.
Rule	**T**: What **has been** so **will continue to be** so.	**P**: What **is here** so **is there** so.
Justification	Rule **T** succeeds for **the past**. ——————(**T**) Rule **T** succeeds for **the future**.	Rule **P** succeeds for **here**. ——————(**P**) Rule **P** succeeds for **there**.

Figure 9: Hume's classic problem of induction and the cosmological correlate.

We see here a general problem for cosmological inference via enumerative induction. It is the difficulty underlying the justification of CP.[37] The authors of the passages quoted earlier in this section recognized, but struggled to articulate, the difficulty with justifying CP. The preceding analysis pinpoints it.

The foregoing result is uniquely acute in the multiverse setting. In most of the mature sciences, including traditional (single-universe) cosmology, iteration after iteration of experience is implemented to strengthen Rule T (or Rule P for traditional cosmologists). Each new experience *A* that proves to be *B* contributes to belief in Rule T. Each new place *A* proving to be *B* contributes to belief in Rule P. Despite this, Hume tells us that we commit a fallacy when reasoning this way. Let us label this fallacy the "Weight of History" fallacy.[38] We cannot accumulate enough confirmation to avoid Hume's problem. Hence, to assume that our experience constitutes "enough experience" to justify our use of Rules T or P is to commit the Weight of History fallacy. Nonetheless, scientists have discounted the Weight of History fallacy for centuries now, because the sciences in question continue to produce results. For example, in traditional cosmology, Rule P is adopted without foundational justification as observations stream in from the cosmos. This much was clear from the series of passages provided earlier in this section.

However, in the multiverse setting, cosmologists arrive at the spatial correlate of Hume's problem *first*—immediately—rather than *eventually*. In attempts to justify the use of enumerative

[37] To see this, substitute "homogeneous and isotropic on large scales" for *B*.
[38] This label was coined by John Norton in personal conversation.

induction between our universe and the other miniverses, the very first step invokes Hume's problem. One cannot accrue some evidence about the similarity (or dissimilarity) between our universe and the other miniverses. *A fortiori*, that process cannot be repeated to gather more evidence. No evidence gathered in our universe provides *any* confirmation about the properties of other miniverses. In the multiverse cosmological case, one never gets a second bit of experience with which to strengthen Rule P. Rule P operates as an inference from a sample of size one, which immediately triggers the need to solve the spatial version of Hume's problem. The resulting situation is so dire that multiverse theorists cannot even put themselves in position to commit the Weight of History fallacy. That is what separates the multiverse case from the standard cosmological case. In the multiverse case, the *premise* in the attempted justification cannot be obtained, let alone the conclusion.

We are now in position to complete the argumentation begun earlier. Recall the goal: it is to acquire independent justification for the use of typicality assumptions, which would foil MCP and erase all of the particular problems presented in the earlier sections of this chapter. So we seek a justification—outside of *MULTIVERSE*—for "Unobserved miniverse *A* is *B*," based upon our knowledge that "Every observed miniverse *A* is *B*."[39]

As should be clear from the analogy with Hume's problem, that justification cannot be forthcoming through enumerative induction: the circularity involved in justifying rule P assures us that any justification for induction from the universe to other miniverses—justification for any typicality assumption—rests upon a circularity. This means that the usage of typicality assumptions in multiverse argumentation cannot be justified via enumerative induction, which is the leading candidate offered by cosmologists to perform the task of cosmological induction.

The result is that simple assertion through *MULTIVERSE* (iii) is the lone extant justification for typicality assumptions involved in multiverse cosmology. Accordingly, typicality assumptions remain *assumptions* and nothing more. While justification of another sort may be forthcoming, the burden of proof lies with the multiverse theorist to provide it. Barring that, the second conjunct of MCP obtains: the use of typicality assumptions is justified only through invoking

[39] The content of *B* will tell us whether we are dealing with the Typicality assumption or the Atypicality assumption. Further, note that the issue already raised against the (IND) pillar applies directly to the premise in the inference: "Every observed place *A* is *B*" merely reduces to "The universe is *B*." No further "places" (miniverses) can accumulate beyond the universe. Here, we waive this problem to see the larger problem involved with justifying the use of typicality assumptions.

MULTIVERSE. By coupling this with the result of Chapter 7 (namely, that *MULTIVERSE* is justified only through invoking typicality assumptions), the Multiverse Circularity Problem is established.

The case involving CP revealed that typicality assumptions are not unique to multiverse cosmology. So, one may wonder whether there exists a correlate of the MCP that is not multiverse-specific. The answer is that the first conjunct of the MCP—that *MULTIVERSE* is justified only through invoking typicality assumptions—is not a condition that obtains broadly for cosmological theories; other theories, perhaps of the *UNIVERSE* denomination, might be justifiable independently of their implementation of typicality assumptions (such as CP). Perhaps the circularity revealed here *does* hold in some suitably adjusted fashion for cosmological theories of another type, but that is an undertaking of a different sort.

9
Conclusion: A Path to Solutions

The foregoing analysis suggests that the multiverse hypothesis requires strengthening if it is to become a leading cosmological position. The emergence of the historical context of the multiverse tradition and the uncovering of the Multiverse Circularity Problem (MCP) create paths for multiverse theorists to pursue. Intended as a map for future research, this chapter closes the present project by taking the first tentative steps along two of those paths. Historical considerations are warranted to account for the trajectory of the multiverse tradition in relation to the trajectory of cosmology historically. Philosophical considerations are warranted due to the lack of development regarding the specific assumptions, principles, and stances that are necessary for the consistent advancement of the multiverse hypothesis. By pursuing these two avenues, multiverse theorists could begin to answer the doubts raised about the multiverse hypothesis that arose in the preceding chapters.

The unique situation facing the cosmologist is that cosmological theories are neither clearly science nor clearly philosophy. Multiverse theorists face many of the same difficulties that have faced cosmologists throughout the history of the discipline. Accordingly, developments must take place along both facets—the scientific and the philosophical—for multiverse cosmology to advance satisfactorily.

It should be emphasized that the following work provides merely the *next* step in a continuing analysis of the multiverse hypothesis. Accordingly, it is reasonable to expect that each of the presented considerations is likely to undergo substantial development after receiving its own extended, focused research program.

9.1 Development of the Historical Context of Multiverse Cosmology

The historical portion of this project (Chapters 2-5) demonstrated that historical study *internal* to the multiverse tradition—i.e., within the multiverse tradition—can prove fruitful for analyzing the tradition's models and arguments. In this section, it is suggested that historical study *external* to the multiverse tradition might likewise prove instructive for anticipating the trajectory of the multiverse tradition itself within the history of cosmology. That is, it may prove fruitful to investigate the arrival of contemporary multiverse cosmology—and appraise its reception—within the context provided by the history of cosmology. Specifically, it appears that the contemporary multiverse movement might generate a revival of the public debate about the state of cosmology that occurred during the first half of the twentieth century. Here we pursue, only to a shallow depth, the clearest similarities between the two episodes with the aim of gaining perspective for the contemporary setting.[1]

Milne's presentation of kinematic relativity created a stir in the early part of the twentieth century. By championing a hypothetico-deductive approach to cosmology in opposition to the entrenched inductivist approach, Milne invoked the ire of Dingle.[2] Milne advocated the generation of theory, followed by the deduction of potential observations from that theory, which could then be empirically tested. At the core of Milne's proposal is the Cosmological Principle (CP).[3] Dingle, in retort, argued that such a stance removes one's activities from the realm of science, which is governed foremost by empirical observation. A scientist, after collecting empirical data, would then generalize to obtain a theory. Dingle leaves very little to interpretation:

> The new Aristotelianism has now grown so confident that we have no need to unmask it: it has itself discarded masks, and we have only to recognize it for what it is…Prof. E. A. Milne's "kinematical relativity" has quite a different character. Here we not only establish mechanics on 'The Universe' instead of on Newton's "manifest phenomena", but also we invent our own universe so as to be seraphically free from the least taint of observability. This creation is defined by the "Cosmological Principle", which selects out of all conceivable bodies those which, if they had observers on them, would restrict the behavior of such observers to a certain mutual conformability.[4]

Bondi's steady-state cosmology espoused Milne's methodological approach by enhancing CP, causing it to apply with both spatial and temporal reach:

> Our course is therefore defined not only by the usual cosmological principle but by that extension of it which is obtained on assuming the universe to be not only homogeneous but also unchanging on the large scale. This combination of the usual

---

[1] For a full account of the details pertaining to cosmological debate in the early-to-mid twentieth century, as well as an extensive list of the relevant references, see Gale (2014).
[2] See Dingle (1937).
[3] The Cosmological Principle is the claim that the universe is homogeneous and isotropic at large scales. See Chapter 8 for discussion.
[4] Dingle (1937), p. 785.

> cosmological principle and the stationary postulate we shall call the *perfect cosmological principle*, and all our arguments will be based on it. The universe is postulated to be homogeneous and stationary in its large-scale appearance as well as in its physical laws.[5]

Opponents of cosmological research that was grounded by Milne's CP or Bondi's Perfect Cosmological Principle (PCP), such as Dingle, viewed such research as unfounded due in part to its departure from the mainstream practice already in place in the discipline.

The apparent novelty of the upstart approach to its proponents—Milne's kinematic relativity in the 1930s, Bondi's steady-state cosmology in the 1940s, and multiverse cosmology presently—offers an initial similarity between the two settings. Gale suggests (about early twentieth century cosmology) that "part of the controversy may be laid to the fact that cosmology was a new science, and disputes about methodology in new sciences are not rare in the history of the sciences."[6] Indeed, though it is clear that the reach of the multiverse tradition disqualifies it from genuine novelty, those currently partaking in the debate often are not aware of the historical tradition.[7] Part of the venom in Dingle's attack resides in his accusation that his contemporaries were neglecting to notice that they were reviving long-overthrown Aristotelian modes of reasoning. Against that defeated position, Dingle champions the Galilean approach. Similarly, the methodology practiced by contemporary multiverse theorists appears to be novel, though in fact it is not.

Beyond the apparent—but illusory—novelty of the upstart positions, the core methodological similarities between the two episodes warrant attention. The foundation of Milne's kinematic relativity was his espousal of CP, and the foundation of Bondi's steady-state cosmology was his extension of CP to PCP. Both instances represent the hypothetico-deductive approach that directly opposed Dingle's preferred inductivist stance. Likewise, multiverse cosmology relies heavily upon the hypothetico-deductive approach. This is true regardless of which type of multiverse model one proposes, since each argument in support of the multiverse incorporates a typicality assumption.[8] The relationship between CP, PCP, and typicality assumptions is clear: CP and PCP are simply individual instantiations of the Typicality Assumption. Indeed, as will be seen in the following section, some multiverse theorists even endorse CP itself. Accordingly, it is clear that

[5] Bondi & Gold (1948), p. 254. Emphasis in original.
[6] Gale (2014), p. 4.
[7] See Chapter 2.
[8] See Chapter 6.

kinematic relativity, steady-state cosmology, and multiverse cosmology all rely on principles, assumptions, and theory, rather than empirical evidence, as their points of departure.

Furthering the case for similarity, the primary contemporary attack on the multiverse hypothesis mimics Dingle's outcries from the twentieth century. Opponents of multiverse cosmology claim that it is not scientific to present argumentation that is not rooted directly in observational evidence. *MULTIVERSE* (ii) triggers this retort; the clause generates accusations that the multiverse hypothesis cannot be scientific.

Even still, Kragh notes of the multiverse stance that:

> The claim has become part of scientific discourse and won acceptance in a not insignificant part of the community of theoretical physicists and cosmologists. What used to be a philosophical speculation is now claimed to be a new paradigm in cosmological physics, meant to replace the traditional ideal of explaining the universe and what is in it in a unique way from first principles.[9]

Nonetheless, the "not insignificant part of the community" that adopts the multiverse position faces resistance from the rest of the community. Argumentation from the opposing side evokes the mantras of Dingle. For example, Ellis argues that

> Ensemble proposals are not scientific in the usual sense. In order to make them so—e.g. by showing they are based on a theory that has gained credibility by unifying or clarifying some other mysteries—one has to search for extended ways of relating them to observations.[10]

Elsewhere, Ellis strengthens his position in ways that would surely gain the approval of Dingle:

> But now astrologers can take hope from the arguments of string theorists and multiverse enthusiasts: with the weakened kinds of criteria proposed, astrology too will soon be a strong candidate for recognition as a genuine science…It is a retrograde step towards the claim that we can establish the nature of the universe by pure thought without having to confirm our theories by observational or experimental tests.[11]

Dingle's "modern Aristotelians" have been replaced by Ellis's "astrologers" and Dingle's warning against relying exclusively on "invention" has been replaced by Ellis's warning against relying exclusively on "pure thought," but there is no mistaking the fact that the message is the same. Ellis does not call upon the history of the discipline, nor does he reference Dingle's work in particular, but his opposition to multiverse cosmology is voiced with precisely the same argumentative structure as Dingle's opposition to kinematic relativity.

[9] Kragh (2011), p. 255.
[10] Ellis (2007), p. 400.
[11] Carr & Ellis (2008), p. 2.35.

To be sure, there are relevant methodological differences between Milne's position and *MULTIVERSE*. The most important of these is Milne's steadfast adherence to the deduction component of the hypothetico-deductive stance, which culminated in Bondi's bolstering of the component via Popperian falsificationism.[12] It is an aspect of the methodology that multiverse theorists appear to be restricted from embracing, since *MULTIVERSE* (iii) makes *any* physically possible observation a consequence of the multiverse hypothesis.[13]

A further difference might be present with the subset of theorists embracing (IND). Those theorists appear to take an approach quite close to Dingle's inductivist approach. Nonetheless, even the multiverse argumentation conforming to (IND) requires an initial typicality assumption—often CP itself, to which Dingle directly objected—in conjunction with its observational component. That factor provides some distance between the (IND) approach and Dingle's preferred methodology.

Undertaking an extended, rigorous investigation of the likeness between the rise of the contemporary multiverse hypothesis and the onset of kinematic relativity and steady-state cosmology in the twentieth century might provide useful insight for cosmologists. In the early twentieth century, the "new" methodology—the side embracing theory founded upon principles—won the debate.[14] But the win was temporary: some of those principles (PCP, for example) were demonstrated to be false, and likewise for the cosmological models founded upon them. That lesson might prove invaluable for contemporary multiverse theorists as the tide turns presently in their favor. A similar outcome may be on the horizon for multiverse cosmology, which would justify a concentrated focus on the principles currently governing multiverse argumentation. Leaving assumptions and principles unjustified or implicit can result in unnoticed foundational problems.[15] Instead, multiverse theorists should develop explicit formulations of the principles that are necessary for argumentation in multiverse cosmology. Making the principles explicit would enable theorists to recognize the tenuous justifications currently in place, which would, in

[12] See Gale (2014), pp. 31-33.
[13] Despite this, there are examples of multiverse theorists attempting to satisfy the falsifiability criterion. See, for example, Smolin (2007). Section 9.3 contains additional (albeit brief) discussion of this point.
[14] See Gale (2014), pp. 26-30.
[15] See Chapter 8.

turn, prompt them to make progress with respect to justifying those assumptions and principles. It is to the task of developing multiverse-specific versions of the standard principles in cosmology that we now turn.

9.2 Development of the Philosophical Context of the Multiverse Hypothesis

The philosophical portion of this project (Chapters 6-8) demonstrated that principles and assumptions are foundational within multiverse argumentation. Such principles, including CP, WAP, SAP, and general typicality assumptions, often remain implicit. Furthermore, many of the principles are outdated, since they arose within the context of standard (non-multiverse) cosmology. To assume that a unified set of principles and reasoning governs both cosmological cases (*UNIVERSE* and *MULTIVERSE*) is a mistake; the mere extension of traditional cosmological concepts and principles to the multiverse scenario is not an automatic process. Thus, one option for solving the MCP and the other problems identified in Chapter 8 might involve updating the principles employed by multiverse theorists. A second option might involve developing argumentation for the multiverse that eschews typicality assumptions altogether. In this section, initial forays in both directions are considered. Suggestions are provided for updating some of the most widely implemented principles in multiverse argumentation. Additionally, the Ignorance Assumption is presented as an alternative to the typicality assumptions that currently dominate multiverse argumentation. The caveat provided at the beginning of the chapter bears repeating: the work in this section is nothing more than a very early sketch of some of the strategies that multiverse theorists could investigate. The suggestions provided here do not solve the philosophical problems identified earlier in the project, but they do offer the multiverse theorist options to pursue.

The Cosmological Principle (CP) is perhaps the most prevalent Typicality assumption implemented in cosmology. Its extension to PCP, as outlined in the previous section, also plays a notable role in the history of cosmology. Both principles have remained essentially unaltered since their emergence in the discipline, and both principles are tailored to our universe: they deal specifically with the matter distribution of the universe, and PCP additionally involves the temporal dimension. Neither of those factors is appropriate for a principle tailored to multiverse cosmology, since miniverses are not restricted to containing matter—nor even restricted to exhibiting a temporal dimension.[16] Nevertheless, contemporary multiverse theorists employ CP. For example, Knobe, Olum, and Vilenkin claim that

> The theory of inflation is a scientific theory, and it can therefore be supported by observational evidence…we can gain evidence about events in remote regions of the universe without ever actually observing those events. Drawing on evidence from the observable region, we can construct and test physical theories. These theories will then generate predictions about events outside the observable region, and insofar as we have reason to believe the theories, we have reason to believe the predictions they generate.[17]

The passage advocates a version of CP, presented in Chapter 8 as

> CP: The universe is homogeneous and isotropic on large scales.

However, when wielded by multiverse in the manner described in the passage by Knobe, Olum, and Vilenkin, CP loses its import.[18] Instead, a multiverse theorist requires a principle that speaks not to the properties of the universe, but to the properties of the multiverse and its miniverses.

It is evident that a multiverse correlate of CP cannot make reference to homogeneity. This leaves isotropy as the only content from CP that might likewise apply to the multiverse, resulting in:

> CP_{m+}: The multiverse is isotropic.[19]

Put this way, we see that CP_{m+} is the most basic Typicality assumption applicable to the multiverse: the view from any miniverse is the same. It thereby serves the same function for multiverse cosmology that CP serves for standard (single-universe) cosmology.

The conundrum that arises is that CP_{m+} represents the antithesis of most contemporary multiverse models. In fact, Ellis notices this discrepancy in argumentation involving spatially extended multiverse models:

> For if the universe within the horizon is almost exactly Friedmann-Robertson-Walker (FRW)—a statistically spatially homogeneous and isotropic space-time—it is plausible that it is also FRW just outside horizon, and a simple extrapolation suggests that it is spatially homogeneous without limit. But supporters of chaotic inflation claim that there are completely different domains out there with different values of the constants, so which is the case? You can say what you like and nobody can *prove* it right or wrong.[20]

---

[16] *MULTIVERSE* (iii) permits the variance in miniverse composition leading to this result.
[17] Knobe, Olum, & Vilenkin (2006), pp. 54-55.
[18] See Chapter 8.
[19] The reason for including "+" in the subscript becomes apparent in the ensuing analysis.
[20] Carr & Ellis (2008), pp. 2.33-2.44.

Inflationary cosmology is precisely the foundation adopted by Knobe, Olum, and Vilenkin in the previous passage where they speak of implementing CP. And, exactly as suggested by Ellis, they conclude that the multiverse overall is *not* isotropic. Instead, they claim that "every possible history has a non-zero probability and will therefore, with probability 1, occur in an infinite number of regions."[21] Accordingly, to make Ellis's conclusion explicit, note that in the multiverse case there appears to be no clear justification for choosing between

CP_{m+}: The multiverse is isotropic.

and

CP_{m-}: The multiverse is not isotropic.

In fact, we see Knobe, Olum, and Vilenkin infer CP_{m-} from observations in the universe that contribute to CP. It is not clear how they infer CP_{m+} rather than CP_{m-} in their multiverse argumentation. In this instance, generating a distinctive multiverse correlate for CP—whether it is CP_{m+}, CP_{m-}, or a different formulation altogether—brings to the fore issues that might remain obscured otherwise. The same approach will now be taken toward two other principles from standard (single-universe) cosmology that receive frequent attention in the multiverse literature: the Weak Anthropic Principle (WAP) and the Strong Anthropic Principle (SAP).

A staple in arguments that conform to the (EXP) pillar of multiverse argumentation, the WAP states that "our location in the universe is necessarily privileged to the extent of being compatible with our existence as observers."[22] Carter, though, applies WAP within the context of *our universe*, not within the context of a multiverse. Specifically, with the term "location" in the passage, he refers to *temporal* location within the setting of our single universe.[23] Accordingly, it is difficult to see how direct implementation of the WAP in a multiverse scenario can occur without suitably adjusting its content. Nevertheless, those in the multiverse tradition routinely appeal to WAP when arguing in accordance with the (EXP) schema.[24]

A suitable adjustment to the WAP in the language governing the present project would amount, minimally, to replacing Carter's use of "universe" with "multiverse": "our location in the *multiverse* is necessarily privileged to the extent of being compatible with our existence as observers." However, it is not our *location* within the multiverse, but rather the *composition* of

[21] Knobe, Olum, & Vilenkin (2006), p. 51.
[22] Carter (1974), p. 293.
[23] See the Prologue for full analysis of Carter's original formulation of WAP.
[24] See Chapter 6.

our universe in the multiverse, that dictates its compatibility with observers. Thus, further adjustments are necessary to the early portion of the principle.[25] A better formulation is:

> WAP_m: The composition of our miniverse within the multiverse is necessarily privileged to the extent of being compatible with our existence as observers.

WAP_m is a first attempt at constructing the multiverse equivalent of WAP. Note the potentially crucial reversal in the content: whereas the WAP restricts the properties of observers (namely, their location), WAP_m restricts the properties of the universe. Such restrictions on the composition of the universe are precisely the cause for most rejections of the SAP. Before considering the interesting consequences of the shift in content presented by WAP_m, we must first perform a similar analysis on the SAP to acquire its multiverse correlate.

Carter's original SAP states that "the universe (and hence the fundamental parameters on which it depends) must be such as to admit the creation of observers within it at some stage."[26] Just as "location" in the original version of the SAP referred to *temporal* location, so too does "at some stage" in the SAP refer to temporal location. However, although our experience reveals that our universe contains a temporal dimension, it is not clear that *every* miniverse in the multiverse setting contains a temporal dimension, nor is it clear that a theorist can refer consistently to temporal location within the multiverse itself.[27] A multiverse correlate of the SAP therefore requires adjustment to the language involving temporal location.

A suitable first approximation for "at some stage" might be "in some miniverse," for just as we are certain that our universe contains a temporal dimension, we are likewise certain that the multiverse contains multiple miniverses. In addition, whereas the language in the original SAP involves "the universe (and hence the fundamental parameters on which it depends)" as its scope, the multiverse equivalent must take "the multiverse" as its scope. The newly adjusted principle thus would be:

> SAP_m: The multiverse must be such as to admit observers in some miniverse.

Two very interesting interpretations of this result are immediately apparent.

Under one interpretation, it could be claimed that SAP_m is the explicit statement of a principle that multiverse theorists typically imply but do not state: the multiverse, by assumption, is such

---

[25] Additionally, recall that *MULTIVERSE* (ii), which requires the causal disconnection of miniverses from each other, truly does make "location" irrelevant with respect to the contents of a miniverse.
[26] Carter (1974), p. 294.
[27] See Chapter 4.

that observers are included within it *as an initial condition*, not as *a derivation*. In those circumstances, the multiverse is implemented by theorists to do precisely what they presumed they were utilizing the multiverse to *avoid* doing, which is to derive our universe without resorting to the qualities that make the original formulation of SAP scientifically unsavory (namely, the clear path to accusations of intelligent design or "faith"). This interpretation of SAP_m strengthens the caution we should take toward the multiverse hypothesis: the traditional formulation of the SAP evokes hesitancy from scientists for its close relationship to "faith," and so the multiverse version should summon that same hesitancy if it contains the same substantive content of the SAP.

However, a second interpretation of SAP_m offers quite a different result. In many—perhaps most—multiverse models, SAP_m is nothing more than a tautologous implication of the model.[28] Thus, a multiverse theorist might claim that SAP_m merely serves for the multiverse hypothesis in the role served by the WAP for the universe hypothesis. Since the WAP is widely regarded as a tautologous, but nonetheless acceptable, principle, interpreting SAP_m in this fashion might support the worthiness of the multiverse hypothesis for acceptance. Further, and in completion of the analysis of WAP_m initiated earlier, this interpretation of SAP_m would dictate that, in the multiverse setting, WAP_m plays the role that SAP plays in the single-universe setting, and SAP_m plays the role that WAP plays in the single-universe setting. The two principles effectively trade roles when updated for the multiverse setting.

Of course, as has been cautioned repeatedly already, the principles suggested here for multiverse cosmology are only first approximations. It is up to the multiverse theorists themselves to adjust them, accept them, or reject them entirely. What the multiverse theorist cannot do, however, is ignore the fact that standard principles from single-universe cosmology do not cleanly and automatically apply in multiverse cosmology. Argumentation for the principles implemented in multiverse cosmology—whatever they may be—is necessary, and currently lacking, in the multiverse literature. Rectifying this is one clear means available to the multiverse theorist for solving the problems raised for the multiverse hypothesis in Chapter 8.

Finally, we investigate one other means that the multiverse theorist might pursue for solving the MCP presented in Chapter 8. Since the necessary inclusion of typicality assumptions in the extant multiverse argumentation generates the MCP, one potential solution would be the development of argumentation in favor of the multiverse via the Ignorance Assumption.

[28] The multiverse model generated by inflationary cosmology might be one example.

Successfully implementing this strategy would yield a novel fourth pillar of multiverse argumentation. Importantly, whereas the three extant schemas ((IMP), (IND), and (EXP)) are susceptible to the MCP owing to their implementation of typicality assumptions, a schema built in accordance with the Ignorance Assumption would not be similarly vulnerable.

Though a sketch of an argument schema built upon the Ignorance Assumption is a project to be undertaken by the multiverse theorists themselves, work involving "ignorance" has in fact received recent attention in the philosophy of science literature. John Norton has developed an account of ignorance contrasted against the standard probabilistic concept of indifference.[29] Further, he considers the application of the concept to cosmology, particularly with respect to the susceptibility of those in the philosophy of cosmology literature to commit the Inductive Disjunction Fallacy, which arises in the multiverse setting when theorists attempt to apply a probability distribution to a tier of miniverses.[30] The attempt to apply a probability distribution to a tier of miniverses is a routine undertaking in the multiverse literature, and one with known difficulties.[31]

However, by building upon Norton's work and generating an argument schema relying on the Ignorance assumption, multiverse theorists might simultaneously avoid the measure problem and escape the MCP. This is so because applying a probability distribution to a tier of miniverses, which leads directly to the measure problem, also coincides with one means of instantiating either the Typicality assumption or the Atypicality assumption. Depending upon what the probability distribution says about the likelihood of a miniverse exhibiting a particular quality across a tier of miniverses, our universe is determined to be typical or atypical with respect to that quality. Thus, by finding a means of argumentation—via the Ignorance assumption—that does not involve the application of a probability distributions to tiers of miniverses, the multiverse theorist would do away with reliance upon typicality assumptions. Developing Norton's account of ignorance suitably within the multiverse setting might be the first step. Multiverse theorists might thereby acquire the initial building blocks for a novel argument schema that is not susceptible to the MCP.

[29] See Norton (2008).

[30] See Norton (2010), pp. 509-511.

[31] For examples of attempts to apply probability distributions to tiers of miniverses, see Weinberg (2000); Knobe, Olum, & Vilenkin (2006); Tegmark et al. (2006); Linde, Vanchurin, & Winitzki (2009); and Vilenkin (2010). For one account of some of the difficulties inherent with applying a probability distribution to a tier of miniverses, see Earman (2009 ms.), pp. 18-23.

9.3 Conclusion

This study, tracing a common thread of thought, has established the multiverse tradition. Furthermore, the vulnerable parts of that tradition have been exposed. Typicality assumptions are a necessary evil in multiverse argumentation. Their necessity was demonstrated in Chapter 7 and their evilness in Chapter 8. The present chapter has taken steps toward alleviating their negative presence, but no illusions should be entertained that a justification for their use is forthcoming. Instead, the path ahead for multiverse theorists might best be labeled "informative": by uncovering the places that typicality assumptions usually hide, those writing in the tradition can be alerted to their presence, where before the infiltration went undetected. One place to start, as suggested, is with the development of explicit principles and assumptions tailored to the multiverse. Making the assumptions and principles explicit should foster awareness. Much like the recent wave of attempts to defend the falsifiability of the multiverse hypothesis, awareness of the issue should generate creative argumentation that might find success.[32]

Awareness needs to be the first step, since this study has shown that the scientists wielding the three pillars of multiverse argumentation, all resting upon typicality assumptions, are doing so unawares of the foundation upon which they build. It is the task of philosophers of science to detect problems such as those presented here, so it is likewise expected that philosophers of science will acknowledge the problems more readily than the scientists will. But the hope is that eventually, the continued use of typicality assumptions in the multiverse tradition might be justified somehow, at least in part, through collaboration between scientists and philosophers of science. To anticipate the shape of such a solution is, alas, beyond reach of the present project.

With respect to the Multiverse Circularity Problem in particular, a few closing comments are in order. The legacy of Hume's problem, the spatial variant of which is the focal point of the MCP, elicits several common dismissals.[33] The attitude uniting most of those dismissals is perhaps best captured with the "No Miracles" response: Hume's problem actually is not a problem. The fact that science works so remarkably well is justification enough for the continued use of enumerative

[32] For an introduction to the interaction between Popper's falsifiability and the multiverse hypothesis, see Kragh (2012), pp. 38-42. For one explicit account of a multiverse theorist attempting to satisfy the falsifiability criterion, see Smolin (2007).
[33] See Howson (2003), pp. 15-19 for a very efficient list of the most common. Howson's structure follows the template laid forth on pp. 12-54 of Salmon (1966).

induction (or other forms of inductive inference). Correspondingly, the objection to the present work would be that cosmologists do not fare any worse than other scientists in their use of induction. The same old philosophical problem should not warrant further discussion.

The response is twofold. First, in some subfields, science is fast approaching a state in which Hume's lesson cannot be ignored. Multiverse theorists are grappling with cosmological induction in a novel setting where Hume's problem emerges far sooner. It is not unreasonable to expect other scientific disciplines to encounter novel manifestations of Hume's problem as well.

Second, the recalcitrance of Hume's problem is such that it demands fresh attention. Decades ago, Salmon made the same request:

> I, too, have faith that the scientific method is especially well suited for establishing knowledge of the unobserved, but I believe this faith should be justified. It seems to me extremely important that some people should earnestly seek a solution to this problem concerning the foundations of scientific inference.[34]

The explicit extension of the problem from the temporal dimension to the spatial dimension, which culminates in the Multiverse Circularity Problem, is meant as a contribution to Salmon's cause. Perhaps it will prompt new perspectives on the problem both from scientists and from philosophers of science. The emergence of the contemporary multiverse hypothesis signals, perhaps for the first time, the need for scientists to address the problem directly. The history of science tells us of scientists—and even Hume himself—neglecting the problem in favor of pursuing further confirmation for their inductive inferences. Multiverse cosmologists cannot do likewise. This makes Salmon's words even more relevant now than they were when he published them almost a half century ago.

The multiverse tradition, weathered as it is with ancient roots, has endured. It stands now at the fore of contemporary cosmology. It has captured the attention of the greats, and it has accumulated its share of opponents calling for its removal. It has seasonally shed its withered pieces and sprouted more resilient buds. The idea that uncountably many worlds exist, and that our frenzied time here might instead be one experience among countless, is both captivating and enticing. It hints at promise for understanding and explaining our experience. Yet without concerted development of its inner workings, the multiverse hypothesis still remains, as it has for so long, merely a chimera.

[34] Salmon (1966), p. 56.

Bibliography

Aristotle. (1986). *On the Heavens.* (W. Guthrie, Trans.) Cambridge, Massachusetts: Harvard University Press.

Aristotle. (1995). *Selections.* (T. Irwin, & G. Fine, Trans.) Indianapolis: Hackett Publishing Company, Inc.

Aristotle. (1996). *Physics.* (R. Waterfield, Trans.) Oxford: Oxford University Press.

Barrow, J. D., & Tipler, F. J. (1986). *The Anthropic Cosmological Principle.* Oxford: Clarendon Press.

Baum, L., & Frampton, P. (2007). Turnaround in Cyclic Cosmology. *Physical Review Letters, 98,* 071301.

Beisbart, C. (2009). Can We Justifiably Assume the Cosmological Principle in Order to Break Model Underdetermination in Cosmology? *Journal for General Philosophy of Science, 40*, 175-205.

Beisbart, C., & Jung, T. (2006). Privileged, Typical, or Not Even That? Our Place in the World According to the Copernican and the Cosmological Principles. *Journal for General Philosophy of Science, 37*, 225-256.

Boltzmann, L. (1895). On Certain Questions of the Theory of Gases. *Nature, 51*, 413-415.

Bondi, H. (1968). *Cosmology.* Cambridge: Cambridge University Press.

Bondi, H., & Gold, T. (1948). The Steady-State Theory of the Expanding Universe. *Monthly Notices of the Royal Astronomical Society, 108*, 252-270.

Boscovich, R. J. (1966). *A Theory of Natural Philosophy.* Cambridge, Massachusetts: The MIT Press.

Boscovich, R. J. (1976). On the Relativity of Temporal Intervals. In M. Čapek (Ed.), *The Concepts of Space and Time* (M. Čapek, & W. Emge, Trans., pp. 225-226). Boston: D. Reidel Publishing Company.

Bruno, G. (1950). On the Infinite Universe and Worlds. In *Giordano Bruno: His Life and Thought* (D. W. Singer, Trans., pp. 225-378). New York: Henry Schuman.

Bruno, G. (1975). *The Ash Wednesday Supper.* (S. L. Jaki, Trans.) Paris: Mouton & Co.

Burnet, J. (1920). *Early Greek Philosophy*. London: Adam & Charles Black.

Butterfield, J. (2014). On Under-Determination in Cosmology. *Studies in History and Philosophy of Modern Physics, 46*, 57-69.

Campanella, T. (1937). *The Defense of Galileo.* (G. McColley, Ed., & G. McColley, Trans.) North Hampton: Department of History of Smith College.

Čapek, M. (Ed.). (1976). *The Concepts of Space and Time.* Boston: D. Reidel Publishing Company.

Carr, B. (2007a). Introduction and Overview. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 3-28). Cambridge: Cambridge University Press.

Carr, B. (2007b). The Anthropic Principle Revisited. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 77-89). Cambridge: Cambridge University Press.

Carr, B., & Ellis, G. (2008). Universe or Multiverse? *Astronomy & Geophysics, 49*, 2.29-2.37.

Carter, B. (1974). Large Number Coincidences and the Anthropic Principle in Cosmology. In M. Longair (Ed.), *Confrontation of Cosmological Theories with Observational Data* (pp. 291-298). Boston: D. Reidel Publishing Company.

Cavendish, M. (1972). *Poems and Fancies, 1653.* Menston: Scolar Press.

Cavendish, M. (1994). *The Blazing World and Other Writings.* (K. Lilley, Ed.) London: Penguin Books.

Charlier, C. (1922). *How an Infinite World May Be Built Up.* Stockholm: Almqvist & Wiksells Boktryckeri.

Cornford, F. (1934). Innumerable Worlds in Presocratic Philosophy. *The Classical Quarterly, 28*, 1-16.

Craig, W. L. (1988). Barrow and Tipler on the Anthropic Principle vs. Divine Design. *The British Journal for the Philosophy of Science, 39*, 389-395.

Cusanus, N. (1954). *Of Learned Ignorance.* (G. Heron, Trans.) New Haven: Yale University Press.

Danto, A. C. (1980). *Nietzsche as Philosopher.* New York: Columbia University Press.

Davies, P. (2004). Multiverse Cosmological Models. *Modern Physics Letters, 19*, 727-743.

Davies, P. (2007). Universes Galore: Where Will It All End? In B. Carr (Ed.), *Universe or Multiverse?* (pp. 487-505). Cambridge: Cambridge University Press.

de Vaucouleurs, G. (1970). The Case for Hierarchical Cosmology. *Science, 167,* 1203-1213.

Dick, S. (1982). *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant.* Cambridge: Cambridge University Press.

Digges, L. (1576). *A Perfit Description of the Caelestiall Orbes, According to the Most Auncient Doctrine of the Pythagoreans.* London: Thomas Marshe.

Dingle, H. (1937). Modern Aristotelianism. *Nature, 139*, 784-786.

Earman, J. (1987). The Sap Also Rises: A Critical Examination of the Anthropic Principle. *American Philosophical Quarterly, 24,* 307-317.

Earman, J. (2009 ms.). Cosmology: A Special Case. (pp. 1-25). Presented at Philosophy of Cosmology: Characterising Science and Beyond (Oxford).

Eddington, A. (1939). *The Philosophy of Physical Science.* New York: The Macmillan Company.

Ellis, G. (2007). Multiverses: Description, Uniqueness and Testing. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 387-409). Cambridge: Cambridge University Press.

Ellis, G., & Brundrit, G. (1979). Life in the Infinite Universe. *Quarterly Journal of the Royal Astronomical Society, 20*, 37-41.

Empedocles. (1981). *The Extant Fragments.* (M. Wright, Ed.) New Haven: Yale University Press.

Epicurus. (1979). *The Extant Remains.* (C. Bailey, Trans.) Westport: Hyperion Press, Inc.

Fournier d'Albe, E. (1907). *Two New Worlds.* London: Longmans, Green, and Co.

Gale, G. (1998). Cosmological Fecundity: Theories of Multiple Universes. In J. Leslie (Ed.), *Modern Cosmology & Philosophy* (pp. 195-212). Amherst: Prometheus Books.

Gale, G. (2014). Cosmology: Methodological Debates in the 1930s and 1940s. *The Stanford Encyclopedia of Philosophy, Spring 2014*, 1-37. Retrieved from <http://plato.stanford.edu/archives/spr2014/entries/cosmology-30s/>

Garriga, J., & Vilenkin, A. (2001). Many Worlds in One. *Physical Review D, 64*, 043511.

Gilbert, W. (1958). *De Magnete.* (P. F. Mottelay, Trans.) New York: Dover Publications Inc.

Gott, J. (1982). Creation of Open Universes from de Sitter Space. *Nature, 295*, 304-307.

Greene, B. (2011). *The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos.* New York: Alfred A. Knopf.

Gribbin, J., & Rees, M. (1990). *The Stuff of the Universe: Dark Matter, Mankind and the Coincidences of Cosmology.* London: Heinemann.

Hacking, I. (1987). The Inverse Gambler's Fallacy: The Argument from Design. The Anthropic Principle Applied to Wheeler Universes. *Mind, 96*, 331-340.

Heraclitus. (1962). *The Cosmic Fragments.* (G. Kirk, Ed.) Cambridge: Cambridge University Press.

Howson, C. (2003). *Hume's Problem: Induction and the Justification of Belief.* Oxford: Clarendon Press.

Hume, D. (1947). *Dialogues Concerning Natural Religion.* (N. K. Smith, Ed.) New York: Bobbs-Merrill Company, Inc.

Hume, D. (1999). *An Enquiry Concerning Human Understanding.* (T. L. Beauchamp, Ed.) Oxford: Oxford University Press.

Huygens, C. (1757). *Cosmotheoros: or Conjectures Concerning the Planetary Worlds and Their Inhabitants.* Glasgow: Robert & Andrew Foulis.

Kahn, C. H. (1994). *Aniximander and the Origins of Greek Cosmology.* Indianapolis: Hackett Publishing Company, Inc.

Kant, I. (1981). *Universal Natural History and Theory of the Heavens.* (S. L. Jaki, Trans.) Edinburgh: Scottish Academic Press.

Kargon, R. H. (1966). *Atomism in England from Harriot to Newton.* Oxford: Clarendon Press.

Kelly, S. (1965). *The De Mundo of William Gilbert.* Amsterdam: Menno Hertzberger & Co.

Kirk, G. (1955). Problems in Anaximander. *The Classical Quarterly, 5*, 21-38.

Kirk, G., Raven, J., & Schofield, M. (1983). *The Presocratic Philosophers.* Cambridge: Cambridge University Press.

Knobe, J., Olum, K. D., & Vilenkin, A. (2006). Philosophical Implications of Inflationary Cosmology. *The British Journal for the Philosophy of Science, 57*, 47-67.

Kragh, H. (2011). *Higher Speculations: Grand Theories and Failed Revolutions in Physics and Cosmology.* Oxford: Oxford University Press.

Kragh, H. (2012). "The Most Philosophically of All the Sciences": Karl Popper and Physical Cosmology [Preprint]. Retrieved from http://philsci-archive.pitt.edu/id/eprint/9062

Landsberg, P., & Park, D. (1975). Entropy in an Oscillating Universe. *Proccedings of the Royal Society of London, 346*, 485-495.

Leslie, J. (1988). No Inverse Gambler's Fallacy in Cosmology. *Mind, 97*, 269-272.

Leslie, J. (1989). *Universes.* London: Routledge.

Linde, A. (2007a). The Inflationary Multiverse. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 127-149). Cambridge: Cambridge University Press.

Linde, A. (2007b). Sinks in the Landscape, Boltzmann Brains, and the Cosmological Constant Problem. *Journal of Cosmology and Astroparticle Physics, January,* 1-39.

Linde, A., & Vanchurin, V. (2010). How Many Universes Are in the Multiverse? *Physical Review D, 81*, 083525.

Linde, A., Vanchurin, V., & Winitzki, S. (2009). Stationary Measure in the Multiverse. *Journal of Cosmology and Astroparticle Physics*, *January*, 1-20.

Lucretius. (1951). *On the Nature of the Universe.* (R. Latham, Trans.) Baltimore: Penguin Books.

Machamer, P., Darden, L., & Craver, C. F. (2000). Thinking About Mechanisms. *Philosophy of Science, 67,* 1-25.

Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation.* San Francisco: W. H. Freeman and Company.

More, H. (1646). *Democritus Platonissans, or, An Essay upon the Infinity of Worlds out of Platonick Principles.* Cambridge: Roger Daniel.

Mosterín , J. (2004). Anthropic Explanations in Cosmology [Preprint]. 1-42. Retrieved from http://philsci-archive.pitt.edu/id/eprint/1658

Nietzsche, F. (1974). *The Gay Science.* (W. Kaufmann, Trans.) New York: Vintage Books.

Norton, J. D. (1999). The Cosmological Woes of Newtonian Gravitation Theory. In H. Goenner, J. Renn, J. Ritter, & T. Sauer (Eds.), *The Expanding Worlds of General Relativity: Einstein Studies, volume 7* (pp. 271-322). Boston: Birkhäuser.

Norton, J. D. (2008). Ignorance and Indifference. *PHilosophy of Science, 75*, 45-68.

Norton, J. D. (2010). Cosmic Confusions: Not Supporting versus Supporting Not. *Philosophy of Science, 77*, 501-523.

O'Brien, D. (1969). *Empedocles' Cosmic Cycle: A Reconstruction from the Fragments and Secondary Sources.* Cambridge: Cambridge University Press.

Oresme, N. (1968). *Le Livre du Ciel et du Monde.* (A. D. Menut, A. J. Denomy, Eds., & A. D. Menut, Trans.) Madison: University of Wisconsin Press.

Palingenius, M. (1588). *The Zodiake of Life.* London: Robert Robinson.

Pascal, B. (1958). *Pensées.* (T. Eliot, Ed.) New York: E. P. Dutton & Co., Inc.

Randall, L., & Sundrum, R. (1999). An Alternative to Compactification. *Physical Review Letters, 83*, 4690-4693.

Rees, M. (2001). *Our Cosmic Habitat.* Princeton: Princeton University Press.

Robles-Pérez, S., Martín-Moruno, P., Rozas-Fernández, A., & González-Díaz, P. (2007). A Dark Energy Multiverse. *Classical and Quantum Gravity, 24*, F41-F45.

Rubenstein, M.-J. (2014). *Worlds Without End.* New York: Columbia University Press.

Salmon, W. C. (1966). *The Foundations of Scientific Inference.* Pittsburgh: University of Pittsburgh Press.

Sato, K., Kodama, H., Sasaki, M., & Maeda, K.-i. (1982). Multi-Production of Universes by First-Order Phase Transition of a Vacuum. *Physics Letters, 108B*, 103-107.

Schutz, B. F. (2003). *Gravity From the Ground Up.* Cambridge: Cambridge University Press.

Singer, D. W. (1950). *Giordano Bruno: His Life and Thought.* New York: Henry Schuman.

Smith, Q. (1986). World Ensemble Explanations. *Pacific Philosophical Quarterly, 67*, 73-86.

Smolin, L. (1992). Did the Universe Evolve? *Classical and Quantum Gravity, 9*, 173-191.

Smolin, L. (1997). *The Life of the Cosmos.* Oxford: Oxford University Press.

Smolin, L. (2007). Scientific Alternatives to the Anthropic Principle. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 223-266). Cambridge: Cambridge University Press.

Steinhardt, P. J., & Turok, N. (2002). A Cyclic Model of the Universe. *Science, 296*, 1436-1439.

Susskind, L. (2005). *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design.* New York: Little, Brown and Company.

Tegmark, M. (2004). Parallel Universes. In J. D. Barrow, P. C. Davies, & C. L. Harper, Jr. (Eds.), *Science and Ultimate Reality: Quantum Theory, Cosmology and Complexity* (pp. 459-491). Cambridge: Cambridge University Press.

Tegmark, M., Aguirre, A., Rees, M. J., & Wilczek, F. (2006). Dimensionless Constants, Cosmology, and Other Dark Matters. *Physical Review D, 73*, 023505.

Tolman, R. C. (1966). *Relativity, Thermodynamics and Cosmology.* Oxford: Clarendon Press.

Trimble, V. (2009). Multiverses of the Past. *Astronomische Nachrichten, 7*, 761-769.

Vilenkin, A. (1982). Creation of Universes from Nothing. *Physics Letters, 117B*, 25-28.

Vilenkin, A. (1984). Quantum Creation of Universes. *Physical Review D, 30*, 509-511.

Vilenkin, A. (1995). Predictions from Quantum Cosmology. *Physical Review Letters, 74*, 846-849.

Vilenkin, A. (2010). Perspectives in Cosmology. *Journal of Physics: Conference Series, 203*, 1-6.

Weinberg, S. (1972). *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity.* New York: John Wiley & Sons, Inc.

Weinberg, S. (1989). The Cosmological Constant Problem. *Reviews of Modern Physics*, *61*, 1-23.

Weinberg, S. (2000). A Priori Probability Distribution of the Cosmological Constant. *Physical Review D, 61*, 103505.

Weinberg, S. (2007). Living in the Multiverse. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 29-42). Cambridge: Cambridge University Press.

Whitehead, A. N. (1954). *Dialogues of Alfred North Whitehead.* (L. Price, Ed.) Boston: Little, Brown and Company.

Wilczek, F. (2007). A Model of Anthropic Reasoning: The Dark to Ordinary Matter Ratio. In B. Carr (Ed.), *Universe or Multiverse?* (pp. 151-162). Cambridge: Cambridge University Press.

Wright, T. (1750). *An Original Theory or New Hypothesis of the Universe, Founded upon the Laws of Nature, and Solving by Mathematical Principles the General Phaenomena of the Visible Creation; and Particularly the Via Lactea.* London: Chapelle.